THE OFFICIAL ORGAN OF THE ASSOCIATION OF HARVARD ENGINEERS

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A QUARTERLY
DEVOTED TO THE INTERESTS OF ENGINEERING AND ARCHITECTURE AT HARVARD UNIVERSITY

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Frontispiece,

FIG. 4.

THE PASSY BRIDGE, PARIS, FRANCE.

[THE CHARLES RIVER BRIDGES.]

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THE CHARLES RIVER BRIDGES

BY CHARLES W. KILLAM

Assistant Professor of Architectural Construction

Now that the new dam has converted several miles of the lower reaches of the Charles River into a great fresh water basin, destined to be filled with pleasure boats in summer and skaters and ice boats in winter, it is worth while to consider how its various bridges look to the people on the river, and the still greater number who pass over the bridges themselves.

Consider first the bridge nearest the University, that at Boylston Street. It is a pile trestle with small old fashioned double leaf bascule in the middle (Fig. 1.). It is the familiar type of our frugal forefathers who had cheap timber and used it without regard to appearance, permanence, or cost of maintenance. The bridge is crossed by the great crowds going to the games in the Stadium as well as by the students going to their athletic exercises. It is also a link in an important line of inter-suburban circulation connecting Cambridge and Brookline and is much used by automobiles. Its roadway is entirely inadequate in width and there is no satisfactory passage under for boats except at the narrow draw. In appearance it is beneath contempt and should be replaced at once by a handsome bridge. One reason why it is is not replaced is that the War Department insists on such a clearance, 26 feet, that only a draw will answer. It is to be hoped that this restriction will be withdrawn. If a draw must be used for one of the spans, the query is suggested whether the other spans ought not also to be of steel instead of concrete. This query is particularly apropos in this case, because the clearance is very low and arches would be very flat segments springing from close to the water line, thus restricting the passage for

boats under. A bridge of reinforced concrete girder type has been suggested. With this type the architect and layman must become accustomed to what looks like a stone beam but which has a slenderness impossible in stone. Examples already built are not encouraging as to beauty. It would be interesting in this case to study a through plate girder type bridge of three spans with a bascule for the middle span. The piers might be made of stone and as handsome as need be, the girders themselves being made to harmonize with those of the lift span.

Some of the handsome stone piers, supporting the spans of the Paris elevated railroad at street crossings, show the possibilities of the combination of stone piers and steel spans if carefully designed.

Fig. 1.

Below the Boylston Street Bridge, the river is crossed by four other pile trestle bridges which, while not yet as much used as the one at Boylston Street, are open to the same criticisms. That at Cottage Farms is of comparatively recent date and is, it is to be hoped, temporary. Near the mouth of the river there is a maze of trestle work supporting the railroad tracks and yards, a maze which it is reasonable to suppose will be eliminated by rearrangement of the railroad terminal in time. It is impossible to conceive of the Thames or the Seine being crossed by such so-called bridges.

The Harvard Bridge (Fig. 2.) consists of deck plate girders supported on stone piers. The spans are alternately long and short, the latter being cantilevers overhanging each end about

fifteen feet to carry suspended girders over the long spans adjacent. This scheme of construction is not clear from a casual view of the bridge which shows all the girders with arched outline of lower chord. This arching is done presumably for appearance sake, although there may be a slight reason for it in the cantilever girders. It succeeds only in looking weak. There is no other attempt to make the bridge good looking; it simply fulfills the minimum requirements. Nobody would think of erecting a public building in so conspicuous a place without adornment and careful study of its proportions. Why should a bridge be built without the same study?

The Charlestown Bridge (Fig. 3.) is heavier than the Harvard Bridge and is built of deck plate girders resting on stone

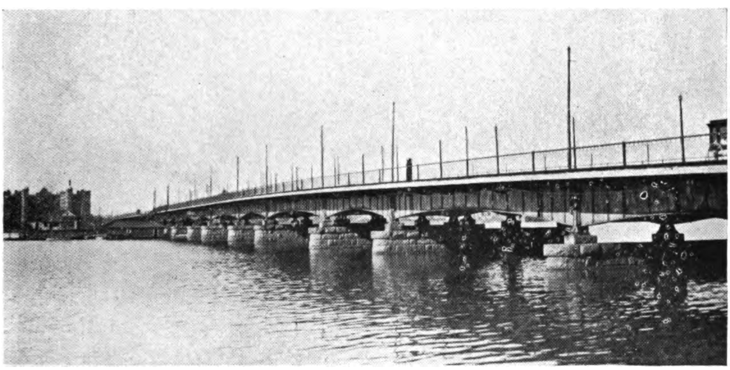


Fig. 2.

piers. It carries the highway and also the elevated railway structure. It has a swing draw with high through trusses giving maximum clearance under at that point. The lower chords of the girders are slightly cambered but there is no other concession to beauty. It has been called "aggressively utilitarian." It may be compared to the Passy Bridge in Paris (Fig. 4.) carrying the highway and elevated structure across the Seine, but it can ill stand the comparison. The Paris bridge is a steel truss cantilever with handsome stone piers and the elevated railway structure was especially designed for the situation, instead of being the ordinary utilitarian affair as carried across the Charlestown Bridge.

The West Boston Bridge (Fig. 5.) is by far the most ornate bridge across the river and probably no bridge in the country of

its type has had more money or effort expended to make it handsome. It consists of eleven spans of two hinged arched plate girders resting on stone piers and with roadway supported on vertical steel columns rising from the arched girders. The spans increase from 101.50 feet next the abutments to 188.50 feet in the middle and the piers increase in width and height. The whole structure was carefully studied in the office of the City Engineer of Boston with the late John E. Cheney directly in charge and with the collaboration of Edmund M. Wheelwright as architect. They studied for two years the numerous possibilities of pier spacings and widths, camber of floor and curves and depths of each span of arched girders until the most pleasing arrangement was found. These variations in dimensions increased the cost

FIG. 3.

but the mid-channel span was required to be higher and wider than the others anyway and the result is so much more pleasing than absolute uniformity that the study was well worth while. If a certain amount of money is to be spent on a succession of piers and arches, why not see that the arrangement is such that they will be pleasing as well as strong? All the details of the bridge such as pier ornaments, iron railings and other accessories were carefully studied in models. The stone cutting is carefully graded to suit its position, being rock face up to the water line, then rough pointed up to the roadway level and six cut on parapets, towers and other parts near the eye. The deepest part of the channel, at the middle, is marked by the widest span with highest clearance and with the largest and most ornamental piers carry-

ing the coats of arms of the two cities connected by the bridge. This middle of the bridge is further marked by granite towers, two on each of the large piers at the sides of the wide span and there are two smaller towers at each end of the bridge. The towers at the middle of the bridge have been criticised because they are so far apart that, when seen in perspective, they seem scattered and also, because they interfere with the continuity of the camber of the bridge. One may question whether they might not have been better omitted, perhaps at the same time increasing the importance of the end towers. This bridge, like the Washington Bridge in New York, the Eads Bridge in St. Louis, and many other fine bridges with steel arches resting on stone piers, continues the stone piers from the springing line of the arches

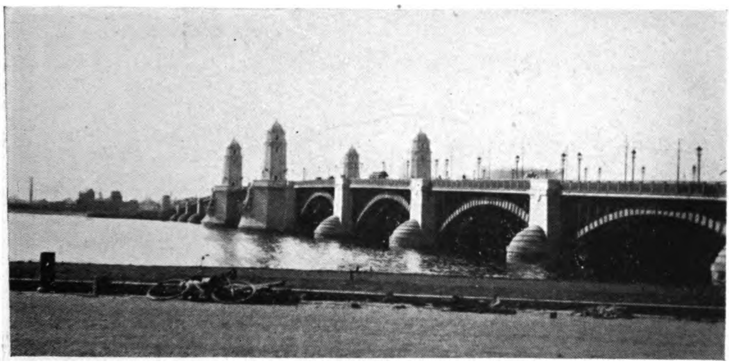


Fig. 5.

up to the roadway level. This custom is probably an inheritance from the masonry arch bridges, but it is evidently done only for appearances as the vertical steel columns which carry the roadway over the arches could just as well carry it over the piers at much less expense than the stone piers. It would be interesting to know whether the greater appearance of continuity given by using the steel supports would balance the advantage of monumental permanence given by the high stone piers. The bridge, as built, cost two and a half million dollars, excluding temporary bridge, permanent approaches and land takings, and a masonry arch bridge was estimated to cost more than twice as much. It is interesting to note that architectural services cost $36,000.00 or, roughly, only 1.6% of the cost of the bridge. The whole bridge

is so handsome and dignified that an American can show it to an European without shame and can feel a sense of pride in the two cities which built it. To any thoughtful person it is a definite addition to the enjoyable things in the Metropolitan District.

At Watertown there is a new bridge of reinforced concrete with quarry-face granite facing (Fig. 6.). The edges of the skewbacks disappear into the projecting piers and also into the

Fig. 6.

water in a disquieting way and the balusters are too large, the posts too small and too close together. Cut granite balusters are not in keeping with a quarry face bridge; a plain parapet would be better. As in many other bridges with wing walls of the abutments continuing in the same plane as the face of the arch the designer has found it difficult to stop the parapet gracefully at the end, using in this case a vertical post which does not course in with the rest of the stonework.

The latest bridge across the river is the viaduct now being built for the elevated railway alongside the new dam (Figs. 7 and 8). The problem here is peculiar. The elevated tracks are to be carried on a concrete arched viaduct some twenty-five feet above the level of the dam and adjoining it on the harbor side where there is a tidal range of nine or ten feet. The viaduct must be arranged so that surface tracks may also be carried under the arches on a future lower bridge if required. The arches, therefore, will consist of two ribs twenty-five feet apart in the clear and the piers above the level of the dam will also be open to the same width to allow the passage of the future surface cars. As the viaduct is so close to the dam there will be no boating under

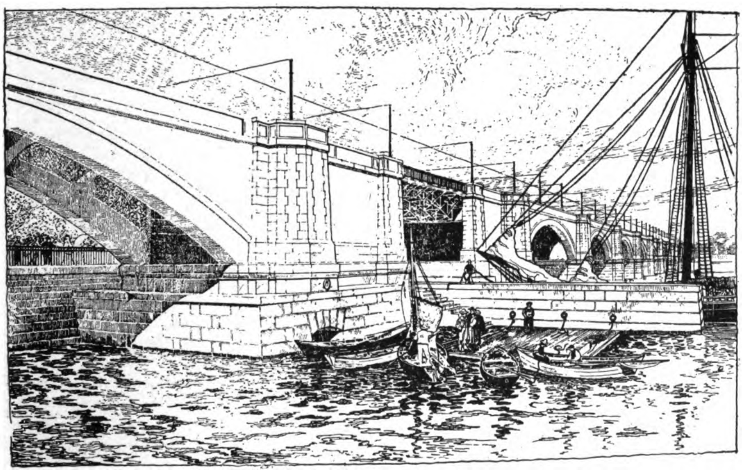


Fig. 7.

it except at the locks, so there is no need of a high camber like the West Boston Bridge, and it will, therefore, be built level for greater economy of train operation. There is no need of cutwaters because there is no current flowing through, but the piers have projecting octagonal ends around which the parapet will be carried, giving the effect of bastions. The lower part of the piers is built of granite as better withstanding the action of frost between high and low tide levels. In this connection it is worth while remembering that any stonework below high tide level may as well, usually, be quarry face as it will be covered with moss and slime anyway but where, as in this case, the octagonal faces and the returns of the bastion divided the granite into rather

small areas the dressed surface is better as the outlines of any but the largest surfaces would be obscured by the varying projection of quarry face stones. Hence the large surfaces of the dam showing adjacent to the viaduct piers look well in quarry face while the much smaller surfaces of the octagonal bastions need to be dressed to make their angles and outlines clear.

The viaduct is being built by the Boston Elevated Company under the direction of George A. Kimball, Chief Engineer of Elevated and Subway Construction, with J. R. Worcester & Co. as consulting engineers, and Robert S. Peabody as consulting architect, the latter being assisted by an advisory board of architects. The engineers and architects collaborated to get a handsome bridge.

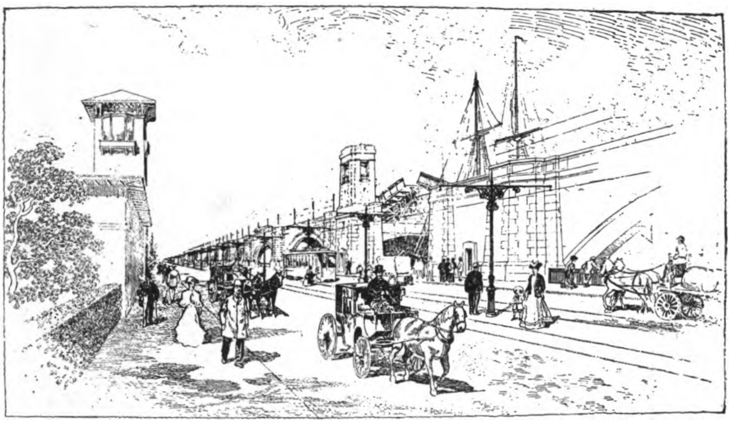


Fig. 8.

Certain locks, sluices, sewers, and levels of the dam had to be arranged for and then the engineers were free to space the piers and outline the arches in any way to get the best effect. Many studies were made at small scale and then at large scale and with models and many samples of concrete finishes have been built. This study is worth while because the viaduct will terminate the basin at its lower end and will also be seen at close range from the roadway and park on the dam. This viaduct when completed, and the West Boston Bridge, will be the only bridges across the river, which, while recognizing the importance of their utilitarian functions as connecting two populous cities, are at the same time beautiful enough to be sources of pleasure.

STRESS VARIATION ON THE SECTION OF AN ANGLE IN TENSION

BY CHARLES J. TILDEN, '96

Assistant Professor of Civil Engineering
University of Michigan

The rolled structural shapes known as angles have been used for many years in riveted work, both for compression and tension members, but it is only recently, in America at least, that attention has been called to the need for more exact methods of stress analysis than those used in current engineering practice. The customary procedure in designing offices is to assume at the outset that the stress on the angle will be uniformly distributed over the cross-section, the gross section being used for compression members and the net section (deducting rivet holes, etc.) for those in tension. In most specifications this assumption is made regardless of the way in which the angle is fastened to the gusset; in Theodore Cooper's specifications for railway bridges, however, the outstanding leg of the angle is not considered effective in resisting stress unless both legs are attached to the plate. The assumption of uniform distribution of stress is manifestly wrong, for, with a single angle, the load coming through the gusset plate must act eccentrically on the section, and therefore cause stresses due to bending, in addition to the stress due to direct axial loading. The rejection of the outstanding leg of the angle, unless it also is fastened to the gusset, is, of course, a step in the direction of safety, but it is purely arbitrary and may or may not bring the maximum stress within the assumed safe working value.

Instead of adopting more rigid methods of analysis, recourse has been had to the results of tests in order to determine what allowances should be made in the design of angle members. But these tests have been carried out with the idea only of getting the ultimate tensile strength of the angle, instead of a determination of the stresses developed under working loads. A typical example of tests of this character was reported a number of years ago by the Ordinance Testing Laboratory of the U. S. A. at Watertown.* This was a 3 in. x 3 in. x 3/8 in. L, about 33 in. long, riveted to a 6-inch hitch-plate at either end. The rivets

*"Tests of Metals" 1896, p. 338.

were of iron ⅝ in. diameter. A clip angle, also 3 in. x 3 in. x ⅜ in. was used to connect the outstanding leg to the plate. The object of the test was to determine, primarily, the strength of the connection, and the data in regard to the angle itself are, therefore, meagre; as it happened, however, the fracture occurred in the main angle, following through the first rivet hole in each leg, i.e., on the zig-zag line. (Fig. 1.). The total maximum load was 50,100 pounds or about 23,700 pounds per square inch of

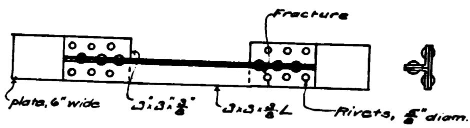


Fig. 1

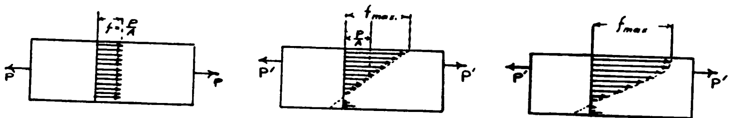


Fig 2

Fig. 3

Fig 4

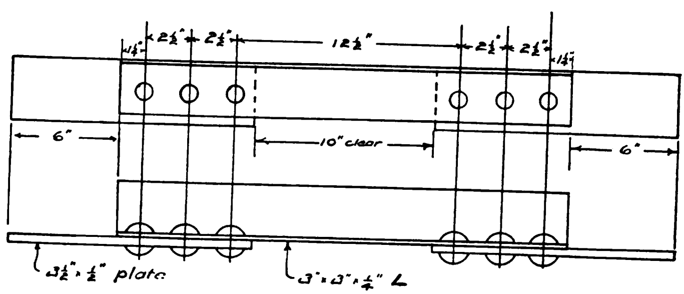


Fig. 5

gross section, 27,200 pounds per square inch of net section (one hole out) or 27,800 pounds per square inch of the actual fractured section, taken on the zig-zag line through the two rivet holes. Although the quality of metal in the angle is not stated it is hardly possible that its ultimate strength, if tested in the ordinary way, would be less than 45,000 or 50,000 pounds per square inch, so that the ultimate strength developed by the specimen was apparently little more than half that of the metal of

which it was made. It is obvious that the stress could not have been uniformly distributed, and that the failure was probably in the nature of a successive tearing of the fibres, beginning at the most stressed edge and continuing across the angle. While such tests are of value in many ways, they do not show the maximum stress on the angle under working loads, which, after all, is the question of greatest importance to the engineer. Moreover, this question cannot be directly answered by means of tests to destruction, which show only the ultimate strength. Possibly a simple example may illustrate this latter point.

Suppose a bar of steel of rectangular section to be subjected to a direct axial pull, P, (Fig. 2) then the stress on any section of the bar will be uniformly distributed, and equal to $\frac{P}{A}$. But if the action line of the load is moved to P^1, a bending stress, as well as a direct stress, is developed, and the resulting stress on the section will be something as shown in Fig. 3, a compressive stress being developed in the bottom fibre in case the action line of P falls outside the middle third of the depth of the bar.*

Suppose, now, that the bar of Fig. 3 is tested to destruction by increasing the load P. The straight line variation of stress holds only so long as the maximum stress is within the elastic limit of the metal. As soon as this limit is passed the outside fibres will yield and pull out, throwing proportionately more stress on the adjacent fibres; the stress conditions will then be, probably, somewhat as indicated in Fig. 4. When the load is carried to such a point that the stress on the outside fibres passes the breaking strength, they will part, and the bar will break gradually, by tearing across. A little thought will show how uncertain, to say the least, is the relation between the maximum stress of Fig. 3, — the working condition, so to speak — and that which exists near the ultimate strength, as in Fig. 4. The conditions which attend tensile tests of angles, carried to destruction are analagous to those of this simple case, although complicated by the form of the specimen and the uncertainty as to the point of application of the load.

These general considerations led the writer to undertake some tests which might throw light on the general question of stress distribution in angles under tension. The problem investigated may be stated thus:—

*See paper by W. E. Dalby, in Minutes of Proceedings, Inst. C. E. CXXXIV, p. 324, for an interesting experimental demonstration of the linear distribution of stress in a flat bar under eccentric load.

Given an angle, riveted at each end to a hitch-plate and subjected to the working tensile load as usually determined (i.e., 16,000 pounds per square inch times the net section,) what will be the distribution of the unit stress on the cross-section?

The specimen used was a 3 in. x 3 in. x 1/4 in. angle, about 2 ft. 1 in. long, riveted at each end to a 3 1/2 in. x 1/2 in. plate, as shown in detail in Fig. 5. The gross cross section of the angle, as determined by actual measurements, was 1.477 square inches and the net section 1.219 square inches, taking out a one-inch diameter hole. At 16,000 pounds per square inch on the net section, then, the total working load is 19,500 pounds. The detail of the joints is open to criticism, as the rivets are pitched too close, and there are hardly enough to carry this load with the factor of safety generally allowed in riveted work, but it was necessary to crowd them somewhat in order to get the specimen into the testing machine and still leave sufficient clear length of angle for the measurement of strains. Under the applied load of 19,500 pounds the rivets showed no weakness whatever. During the test the hitch plates were held in the jaws of the testing machine and all stress transmitted to the angle through the rivets, thus approximating very closely the conditions of practice. The test was made in a 200,000 pounds capacity Riehle two-screw machine, in the testing laboratory of the University of Michigan.

Before putting the specimen in the testing machine, 15 gauge-lines, parallel to the length of the angle, and lettered *a* to *o* on Fig. 6, were scribed on its surface, and prick-punch marks 10 or 12 inches apart, established on each line. A small area near each punch mark was rubbed smooth and coated with a thin film of black drawing ink. The specimen was then put in the machine, and an initial (total) load of about 200 pounds applied in order to take up slack. By means of beam trammels, or dividers, provided with sharp needle points, set at about the gauged length apart, a new gauged length on each of the 15 lines was then established, using first the upper and then the lower punch-mark as a center, one end of the gauged length being the punch-mark and the other a fine line scribed on the prepared surface near the other end. The total load was then increased by 19,100 pounds or an average stress on net section of 15,600 pounds per square inch, equal to about 12,900 pounds per square inch of gross section. The operation with the trammels was then repeated on each of the gauge-lines, while the angle was under this load, thus giving at each end of each gauged length two fine lines whose

distance apart represented the strain or distortion along that line due to the average stress in a length of 10 or 12 inches on that fibre of the angle. Although these lines were very close together, they were readily distinguishable under a glass and their distances apart were then measured to .01 millimeter by a specially devised micrometer. Dividing this small measured length by the gauged length in millimeters gave the unit strain or distortion, from

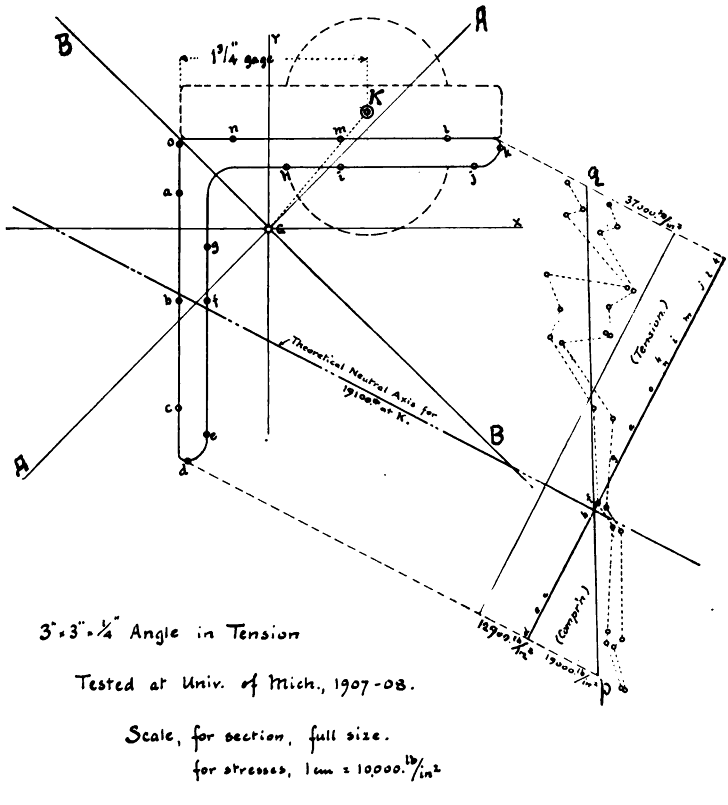


Fig. 6.

which the stress was readily calculated, assuming the modulus of elasticity, E, to be 29,000,000 pounds per square inch. In this manner was obtained a record of the actual stress existing at each one of the 15 points around the perimeter of the angle, resulting from the total load of 19,100 pounds.

These results are plotted and shown graphically on Fig. 6. In each case, i.e., for each lettered gauge line, both observations are plotted, one taken at top and one at bottom. Although these are more or less irregular, the general trend of the stress-variation line is clearly shown, passing from a maximum tensile stress of 35,000 or 40,000 pounds per square inch to a compressive stress of some 20,000 pounds per square inch at the outer edge of the outstanding leg. As a basis of comparison the stresses have been computed, assuming a pull of 19,100 pounds at K, the mid-thickness of the ½-inch hitch-plate and opposite to the gauge line of the rivets in the angle. Finding first the principal axes A—A, and B—B, for the section, and noting the eccentricity of the pull for each axis it is a simple matter to compute the resulting stresses on the section, and from these stresses to determine the neutral axis of the section for a load at K. Projecting the cross-section on a plane parallel to the length of the angle and perpendicular to the neutral axis, the theoretical variation of stress appears as a straight line, pq.

The practical agreement of the theoretical with the observed stresses is suggestive. Aside from the rather crude apparatus used, the angle itself was not perfectly straight, a middle ordinate of about .06 inch in a length of 25 inches being observed before testing. No means were at hand to determine the change in this curvature while the angle was under the load but its effect on the resulting stresses would be comparatively slight. But in spite of the apparent imperfections in this particular test, it would seem that enough had been indicated by the foregoing considerations to warrant the following conclusions:

The assumption of uniform distribution of stress on the cross-section of an angle used as a tension or compression member is a serious error.

Even when the load is figured on the *net* section of the angle, the unit stress on the *gross* section may be far above the allowed working stress.

If the angle is considered as subjected to an eccentric load, whose line of action passes through the mid-thickness of the gusset plate, and the stresses on the cross-section are computed on that basis, it is probable that a close approximation to the actual stress conditions will be attained. Such a procedure would, at all events, come much nearer the truth than the method now commonly used by structural designers.

SOME FEATURES OF THE ALIGNMENT WORK ON THE PENNSYLVANIA TUNNELS

BY FRANCIS MASON, '96

On the recently completed tunnel line by which the Pennsylvania Railroad enters New York City, the alignment work presented some novel features and many interesting problems. In the following notes the more important methods adopted on the East River Division are outlined. This portion of the work extended from the Terminal Station in Manhattan to the point where the tunnels reach the surface in Long Island, a length of about three miles.

Preliminary Surveys. — The extent of the territory to be covered was large, and in order to simplify the connection of the various local surveys and to assist in the plotting of the maps, a system of co-ordinates referred to a pair of arbitrary rectangular axes was adopted. The position of any point or line could therefore be expressed by analytic equations, and the relation of property or existing structures to the proposed lines of the tunnels could be readily determined in the office. The axes selected were parallel to the street lines in Manhattan, and were so located that all of the work was comprised in the first quadrant.

Base Line System. — As a foundation for the surveys and alignment work, a comprehensive system of base lines was laid out, forming in general a series of closed traverses with permanent monuments located at suitable intervals. Of these base lines, the two adjacent to the water front on each side of the East River were the most important, were measured with the greatest care, and served as the primary bases for the river triangulation.

The monuments consisted of a 6-inch wrought iron pipe about 4 ft. 6 in. long, imbedded in a mass of concrete about 2 ft. 6 in. in diameter, from which the pipe protruded about 18 in. The top of the pipe was left about 4 in. below the top of the sidewalk or pavement, and was protected by a cast-iron manhole cover set in concrete entirely independent of the monument itself. A center punch mark on a bronze plug cemented in the top of the pipe defined the point.

Tape Testing. — The base lines were measured with ordinary 100-foot steel tapes about ¼-in. in width. All tapes were

tested for length by comparison with a standard tape, both before and after use. The standard tape had been tested at the Bureau of Weights and Measures in Washington under certain conditions, and its length for the conditions under which it was used was calculated from the certified length. The testing apparatus was permanently installed in one of the company's cement sheds, and was designed to reproduce as nearly as possible the conditions under which the tapes were used in the field. The comparator consisted of two parts. At one end a holder with two slides, adjustable by means of the slow motion thumbscrews, to which the zero ends of the tapes could be attached, was fastened to the wall of the building. At the other end was an accurate double scale set at about the 100 ft. point, and a pair of bicycle wheels over which passed the strings attached to the tape and to the 12 lb. weights which were used for tension. Light hooks suspended from strings at intervals of 20 ft. supported the tapes on a level with their ends.

All tapes to be tested were suspended freely in the air until they had reached the temperature of the room. The standard tape and the one under test were then placed side by side in the comparator, supported at 20 ft. intervals by the suspended hooks, and the tension of the 12 lb. weights was applied. By means of the slow-motion screws, the slides were shifted until the zero points of both tapes coincided with a cross-line on the holder at right angles to the line of the tapes. When adjusted, the scale readings opposite both 100 ft. graduations were read with the help of a magnifying glass to the nearest half-thousandth of a foot. The tension was then released and re-applied, the zero points were again adjusted, and the scale readings at the 100 ft. points were noted. This was repeated a number of times. The position of the two tapes was then interchanged in the comparator and a new set of readings was obtained. Finally, the two weights were transposed and the whole operation was repeated. The mean difference between all the scale readings when applied to the known length of the standard tape gave directly the length of the tape under test. No corrections were necessary, as the conditions were the same for the two tapes.

The results of the tests before and after use seemed to indicate that a permanent lengthening of the tapes occurred while they were in service. On account of the number of tapes broken before a re-test could be made, this feature was not, however, definitely proven. Three tapes in service for four

months showed an increase in length of about 0.002 ft., while one tape of another make and of slightly different cross-section, in occasional use for nearly three years, showed an increase in length of 0.005 ft.

Base Line Apparatus. — The majority of the lines measured were in paved city streets and necessitated the use of somewhat different methods from those commonly employed in base line work. Fixed points at the ends of each tape length were obviously impracticable. A heavy movable casting, called a "spider," was therefore designed to hold temporarily the measurement of each 100 ft. length. Each spider (Fig. 1) weighed about 55 lbs., and consisted of a cast-iron ring with spokes supporting at its center a brass-capped pillar about 12 in. high. Three brass legs threaded for their entire length, were screwed through holes tapped in the cast-iron ring. A few turns of the hand wheel at the top of the leg easily adjusted it to the required height and a lock-nut held it firmly and prevented vibration. The intersection of fine cross-lines on the brass cap of the pillar defined the point of measurement.

The tape when stretched for measurement across the spiders was held firmly at one end by a wooden upright with a base about one foot square, the attachment being made to a wooden block sliding on the upright and adjustable vertically to the required height. The upright was guyed top and bottom, against the pull of the tape, to a spike driven in a convenient crack in the sidewalk. At the other end was the apparatus for applying a constant tension to the tape. It consisted of a 1¼ in. gas pipe frame mounted on three steel legs adjustable for height, by means of which it could be quickly leveled. Sliding longitudinally on the parallel pipes of the frame was a crosshead carrying a bicycle wheel with the fork of the wheel inverted. The stem of the fork was threaded and passed through a large disk nut in the crosshead, providing vertical adjustment for the wheel. A string passing from the tape around the wheel suspended a 12 lb. tension weight. Between spiders the tape was supported at intervals of 20 ft. in hooks suspended from an adjustable arm on a wooden standard. Fig. 1 shows the tension end of the apparatus set up for use.

Method of Measurement. — A transit line was run between monuments, and crosses were cut in the sidewalk at intervals of about 99 ft. Elevations of the sidewalk at the cross marks were then taken, both operations being done during the day, while

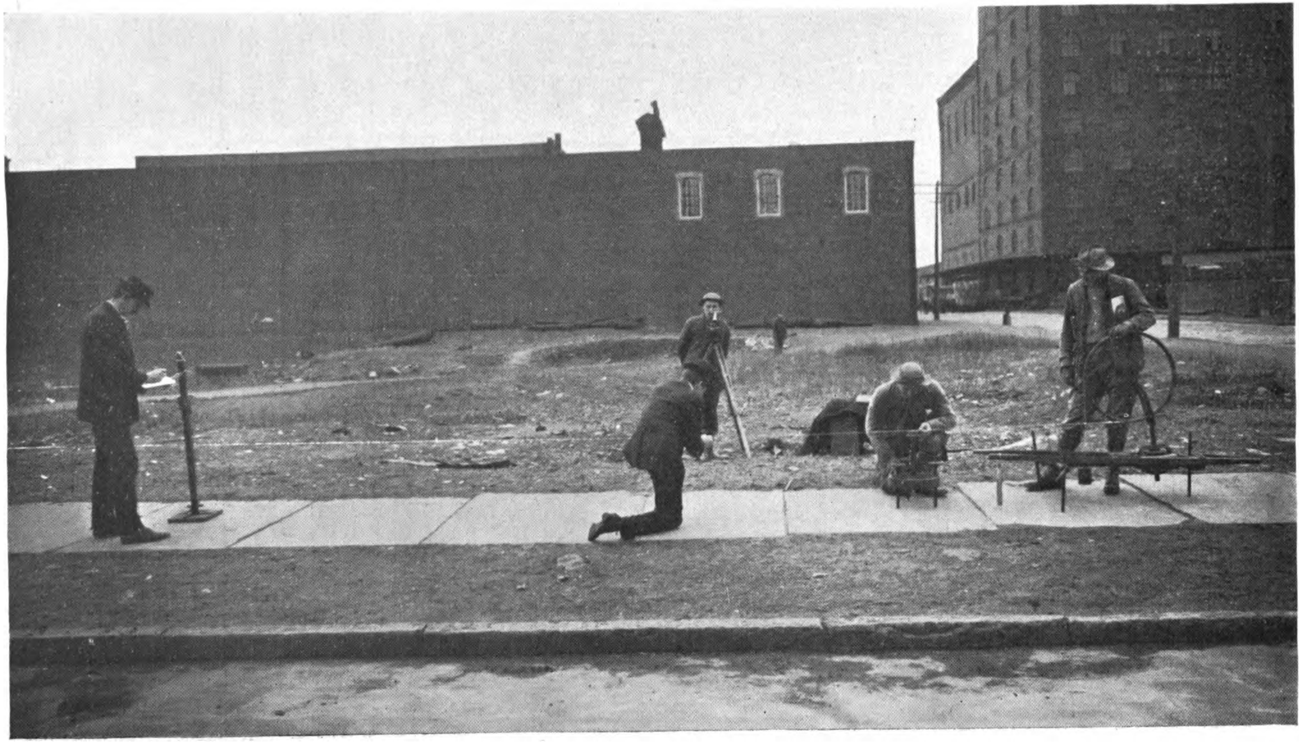


FIG. 1.

actual measuring was done at night in order to minimize the effects of sudden changes of temperature.

The spiders, four in number, were set up over the cross marks, and as the measurement proceeded, the two leading spiders were always in use, the third being left in position in case of accidental disturbance of the second, while the fourth was being moved forward and reset. After stretching the tape between the spiders and adjusting it to the intersection of the cross lines, the intermediate 20 ft. points were hung from the standards on the grade between the tops of the spiders, by sighting in the hooks by eye. The difference in level of the ends of the tape was obtained by measuring with a light rod from the known elevation of the cross on the sidewalk to the top of the spider. With the tape in position, the readings at both ends opposite the cross lines on the spiders were made simultaneously and recorded. The tension of the weight was relieved and applied again and at the same time the point of reading on the tape was shifted a few thousandths by jarring the fixed end standard slightly. The tape readings were again taken and recorded. In general, five sets of readings were made for each tape length, and at the same time the temperature was noted on the thermometers hung on the four intermediate standards. At the ends of the line and at intermediate monuments or transit points, the reading of the tape was made with a transit set at right angles to the base line.

Traffic interfered with the operations to such an extent that the working hours were necessarily short and little was accomplished before 11.00 P.M. An average night's work was about 6000 ft. with a party of seven men, and a total distance of about thirty miles was measured. The base lines on which the triangulation of the river depended were each measured five times, and the remainder four times, except in the case of a few relatively unimportant sections.

In the reduction of notes, corrections for sag and stretch were not necessary, as the tapes were standardized under the same conditions (in these respects) as were used in the field. One foot at each end of the tape was calibrated by comparison with an accurately graduated scale, and a correction was applied to each reading on this account. All thermometers were also calibrated to a standard and the proper corrections were made to their readings. After these preliminaries, the customary corrections for temperature, difference of level, and length of tape

were applied to the measured intervals in the usual manner. The largest probable error was 1 : 130,000 on a line measured both during the day and at night. The smallest was 1 : 2,300,000 on one of the triangulation lines which was measured five times at night. The greater part of the lines showed a probable error of about 1 : 500,000.

Triangulation. — All accurate angle work was done with instruments reading to 10 sec. of arc, separate sets of readings being made by several observers. It was often necessary to place the instruments on narrow places, such as wall copings or

Fig. 2.

timbers, where the ordinary tripod could not be set up. For use in such places, the trivet shown in Fig. 2 was designed, and proved to be an extremely useful accessory.

The various polygons of the base line system were adjusted by adaptations of the familiar methods, modified to suit the particular conditions of the case. The co-ordinates of all monuments were then computed, and together with the azimuths and distances between the monuments, were tabulated and blue-printed for field and office use. Finally the conditions and points governing the location of the tunnels were determined in relation to the base lines, and from their co-ordinates the equa-

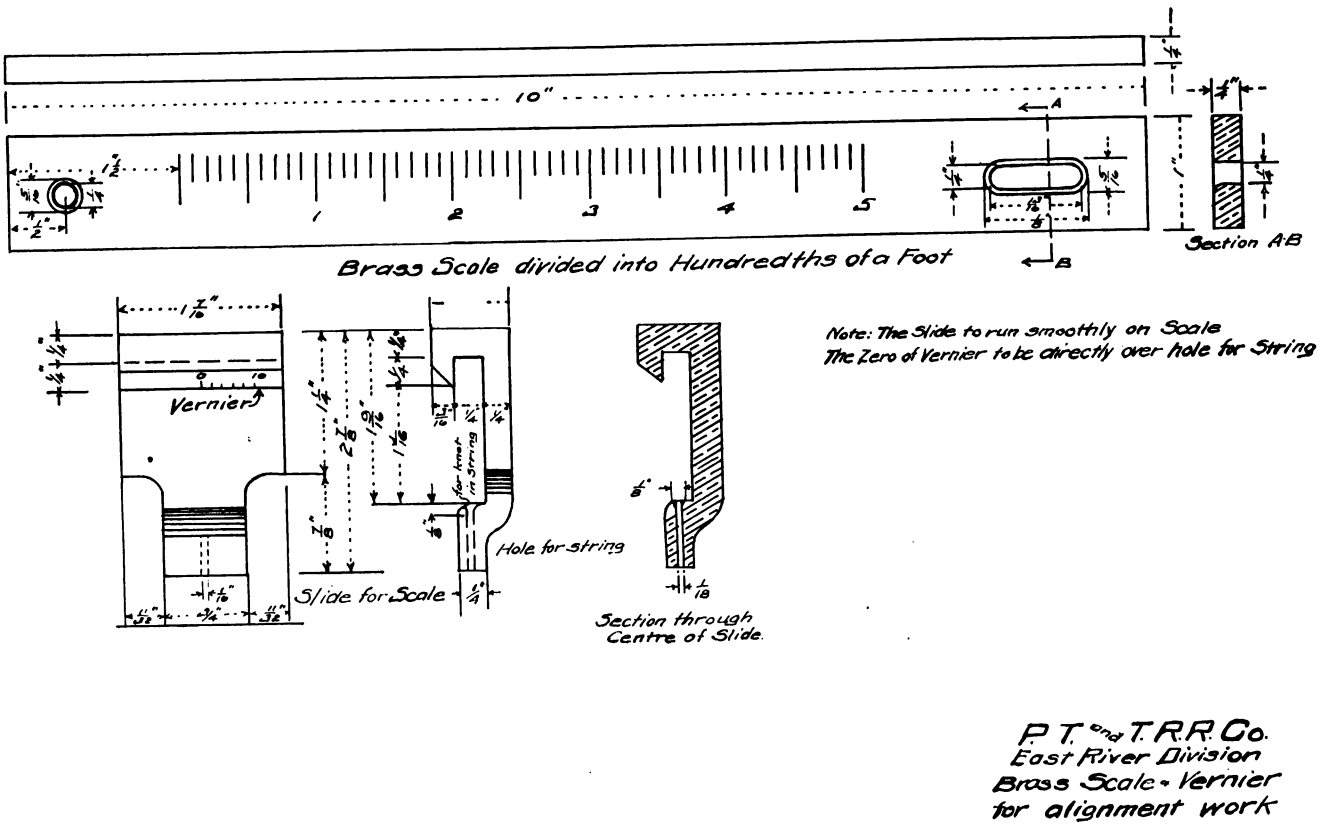
tions of the center lines of tunnels and the co-ordinates of essential points, such as P. C_s, P. T_s, centers of shafts, etc., were computed and tabulated.

Levels. — Levels were transferred across the river from a primary bench by way of the small Astoria Gas Tunnel at the foot of East 71st Street, and in this work the depth of the shafts was determined by two levels reading simultaneously on the top and bottom of a weighted steel tape. The lines were run with ordinary 20 in. wye levels and "New York" rods selected for accuracy of graduation. No special refinements were introduced other than the protection of the instruments from the sun, but the results were entirely satisfactory, as the greatest variation obtained by three observers making six complete circuits was less than 0.03 ft., the distance between bench marks being something over five miles.

Construction Lines. — About 25% of the tunnels were on curves, and in order to secure greater accuracy in laying out the work underground, it was decided to run an engineer's line in each tunnel independent of the center line. On curves the engineer's lines were a series of chords prolonged to intersection. Each chord was as long as could be used after the complete tunnel lining was in place and the angle points were selected for convenience in turning the angles as the work progressed. The number of angles to be turned was reduced to a minimum. On the river tangents, the engineer's lines were fixed at 8 ft. north of the center lines, and parallel to them in order to give a clear sight from shaft to shaft through the short length of curve at the Manhattan end. On the Manhattan tangents, the engineer's lines and the center lines coincided.

The equations of the engineer's lines and their intersections with the base lines near the shafts were computed and the points of intersection were located on the ground. At the river shafts the line of sight between these base line points was soon cut off by the erection of the contractor's plant. A clear line was, however, maintained by the prolongation of the engineer's lines to the roofs of buildings (Fig 2), or by the erection of instrument towers over the points.

One of the most convenient devices adopted for the alignment work was the brass scale shown in Fig. 3. It was graduated to hundredths of a foot, and by means of the vernier, from which a plumb bob was suspended, it was easily read to thousandths. These scales were set permanently in the tunnels wherever re-



10"
Section A-B
Brass Scale divided into Hundredths of a Foot
Vernier
Slide for Scale
Hole for string
for knot in String
Section through Centre of Slide.
Note: The Slide to run smoothly on Scale
The Zero of Vernier to be directly over hole for String
P. T. and T. R.R. Co.
East River Division
Brass Scale & Vernier
for alignment work

FIG. 3.

quired, or were attached to tripods set up approximately over a point to be fixed, and greatly facilitated the averaging of readings for the final location of the point.

Shaft Plumbing. — The plumbing of the shafts, which were about 75 ft. in depth, was done in the customary manner from the lines laid out as described above. Number 8 "music" wire and 30 lb. lead weights were used. The swaying of the wires caused by draughts and falling water was exceedingly annoying, and was not entirely stopped by suspending the weights in water covered with floating sawdust, or in oil. The difficulty was finally overcome by the use of molasses. Each wire was sus-

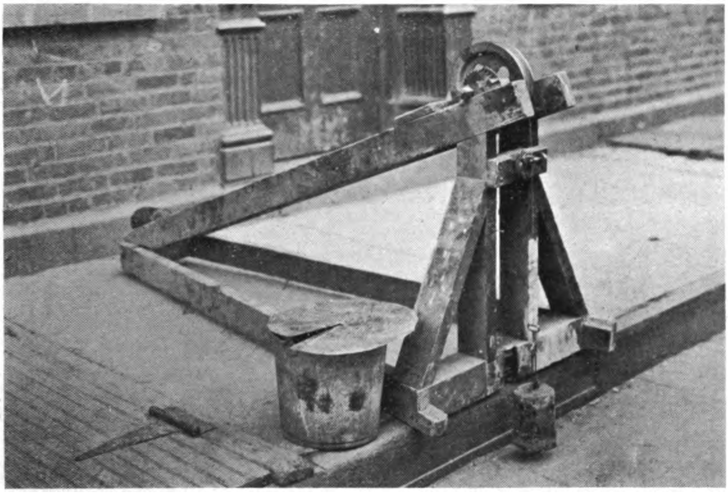


Fig. 4.

pended from a portable frame (Fig. 4) carrying a reel from which the proper length was unwound. The wire hung over a notch in a tangent screw attached to the front of the frame, for adjusting it to the line of sight.

No unusual conditions were present in the shaft plumbing except where, on account of the distance from the line points on the roofs to the shafts, a direct setting of the wires was impossible. In that case scales were set on both sides of the shaft and the line across them was determined on the day previous to the plumbing. For lining the wires, the instrument was set up nearby and bucked into line with the scale readings, and the

wires were set from a backsight on the distant roof points. The line as taken from the wires below was thrown onto scales set permanently in the roof of the tunnels. Enough readings were taken with the instruments, both at the top and bottom, sighting direct and reversed to eliminate the instrumental errors.

Where the shafts were not on the line of the tunnels, an appropriate angle was turned a number of times from the base line to a scale set as far away as possible, and the point thus fixed was used as a backsight in lining the wires. After establishing the plumbing line on scales below, the distance from the base line to the nearest wire was measured on the surface, and the corresponding distance from the wire to the engineer's line was calculated and laid off below. At this point a permanent monument was set in the tunnel floor and from it the calculated angle to the engineer's line was turned off at convenience. Similar monuments, consisting of a short piece of 2 in. pipe bedded in concrete, were set at all important points in addition to the scales. The bronze plug cemented into the pipe and on which the accurate point was center-punched, was protected by a pipe cap when not in use.

Prolongation of Engineer's Lines.—The plumbing of the shafts was repeated from time to time and a careful record was kept of the scale readings and of the conditions under which they were obtained. As the excavation of the tunnels progressed, the line obtained by averaging the scale readings was prolonged to other scales fixed in the roof at intervals of about 300 ft. in the normal air tunnels and about 125 ft. in the compressed air tunnels. In the latter the iron lining was subject to a slight settlement and distortion on leaving the tail of the shield. The accurate scale line was therefore seldom advanced within 200 ft. of the face, nor could it be kept closer in the rock tunnels on account of the liability of displacement of the scales by blasting. Beyond the leading scale the line was carried on spads (horseshoe nails with holes drilled in the flattened heads) driven into plugs set in the roof.

Numerous schemes for prolonging the lines through the bulkheads in the compressed air work were proposed, but were rejected for various reasons. The one finally adopted was the use of a special transit lock. It consisted of a 30 ft. length of 12 in. wrought-iron pipe extending through the concrete bulkhead on the engineer's line. To the outer end was attached a

chamber 24 in. in diameter to permit the door to open inwards. The door on the inner end was hung from a standard pipe flange. Inside each end of the 12 in. pipe was attached a transverse rod with a slide supporting a short plumb-bob. The slide was adjustable to the line of sight by a slow-motion screw operated from outside the pipe. The ends of the lock projecting from the bulkhead were rigidly guyed to the tunnel lining to prevent any movement due to the reversal of the air pressure. Air valves and electric lights at both ends completed the equipment.

In operation, the outer door was opened and the line was prolonged into the lock, the plumb-bobs being carefully set on line, the same as in shaft plumbing. The outer door was then closed, the inner one was opened, and the line, taken from the plumb-bobs, was thrown onto scales in the tunnel beyond. The results obtained by this method were exceedingly gratifying, but the accuracy and speed of the work would probably have been further increased if the short plumb-bobs had been suspended from scales and verniers similar to those used elsewhere.

Wherever the large locks for materials were available, a check on the lines was obtained by setting up the transit in a lock and plunging the line ahead, after locking the instrument and observer through. Adjustable instrument brackets to remain constantly set up on engineer's line were designed for use in the iron-lined tunnels, in the hope of decreasing the time of the field parties in compressed air. Their usefulness was limited, however, and on the whole the ordinary extension leg tripods were found to be more satisfactory.

Checks on Alignment. — The distance between lines in each pair of iron-lined tunnels was checked at the foot of the shaft and at such cross-cuts as were made from time to time, but no discrepancy sufficiently great to require adjustment was found except in one instance. In this case the line at the foot of the shaft passed close to a blacksmith's forge, the radiation from which could not be entirely eliminated. After producing the line for about 1100 ft. from the shaft, a discrepancy of 0.11 ft. as compared with the two adjacent lines was observed, and was adjusted in accordance with the best information obtainable.

No cross-cuts were made in the river tunnels eastward from Manhattan, but after the excavation had proceeded about 1300 ft., 4 in. holes were drilled through the iron lining and the rock

between the two tunnels in each pair. A check through these holes showed the alignments to be only a few thousandths off of parallel.

The river shafts in Long Island City had air-tight floors about two-thirds of the way down, and for several months the lower portion of the shafts was under air pressure. Previous to the placing of the floor, the shaft was plumbed in the usual manner and scales were set on the shaft walls. After the tunnel excavation had advanced about 500 ft. from the shaft, a check plumbing into the compressed air was made in the following manner: 6 in. wrought-iron pipes on engineer's line were carried up through the air-tight floor to the top of the shaft, where they were capped and stayed with turnbuckles. A pinhole was drilled in the pipe cap, and through it was dropped the plumbing wire suspended from an inverted U about 3 in. high, standing on the cap and carefully centered over the pinhole. The wire where it passed through the hole was set on line by adjusting the turnbuckles at the top of the pipe, and was not disturbed by the escape of a small amount of compressed air through the annular opening around it.

Checks on the alignment in the land tunnels were made by drilling 6 in. vertical holes from the surface at convenient distances from the shaft, and dropping a single wire from which the relation of the underground line to the surface base line was determined.

Several of the holes had been drilled for other purposes and were not vertical. One was out of plumb a trifle more than its diameter, but a wire was dropped by suspending it on a known offset from a point a few feet below the surface. Another was both crooked and badly out of plumb, but by carefully setting a transit below and using a prismatic eye-piece, a narrow inclined line of sight was possible and a check was obtained.

Setting Points. — As previously stated, the engineer's line on curves was a series of prolonged chords whose relation to the center line was fixed in advance. Distances on the engineer's line were given the name " Ordinates," to distinguish them from the " Stations " on the center line. In order to reduce the amount of mathematical work in the field and to facilitate the setting of points in the tunnel, ordinate tables were prepared and attached to the field books. These tables gave for every foot on the engineer's line, the distance from engineer's line to center line, the angle between engineer's line and a radius to curve, the station

on center line radially opposite, and the elevation of the neat line in the floor of the tunnel. The computation of the tables involved considerable work, which was, however, amply repaid by the saving of labor in the field. On tangent, tables of elevation of neat line were all that were required.

In the land tunnels the spad line was kept as close to the face of the heading as practicable. As soon as possible after blasting, a cross was painted on the face at center line and a constant distance below the neat line in the roof. The curve of the neat line of the roof excavation was also painted as a guide to the drillers. These points were set either with an instrument or by hanging plumet lamps from the spads at the constant dis-

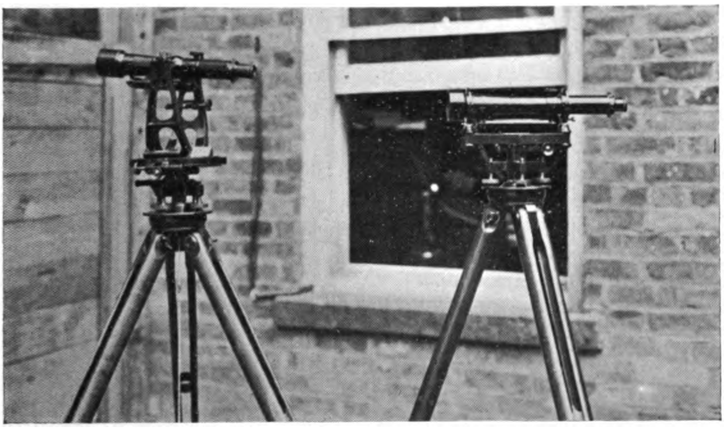


FIG. 5.

tance below neat line and sighting in a point at the face on line and grade, with the flames of the lamps. From the point thus set the center line cross was located by offsetting the proper distance as given in the ordinate tables.

Special Instruments. — A great deal of the instrument work in the tunnels was necessarily performed in dark and restricted spaces and required the use of very short sights. For this purpose the commercial levels and transits were not well adapted. After consultation with the instrument makers, a new type of instrument was designed which fulfilled the required conditions. The objective was of large diameter and wide field, and the eyepiece inverting and of low power, giving good illumination of

the image. Focus was obtained by moving the eye-piece instead of the heavier object glass, and sights as short as 8.3 ft. from the center of the instrument could be obtained with the transit, and 5.7 ft. with the level. Additional short-focus lenses reduced these distances to about 2.2 ft. The modifications from standard design were found to be very successful in general use under the conditions which obtained.

Another and equally useful instrument, built especially for this work, was a large-sized sunflower for cross-sectioning. The graduated circle and the hollow rectangular rods were made of aluminum, the lightness of the latter being particularly advantageous. A small telescope fitted to the center of the dial was at times convenient for locating the position of the instrument.

Shield Checking. — After every shove, the position of the shield and the direction in which it was pointed were determined in relation to the true line and grade. For the former many ingenious devices were tried, but after extensive tests, the transit and level were found to give the quickest and most reliable results. This was largely due to the fact that the iron lining changed its position somewhat on leaving the tail of the shield, necessitating the frequent adjustment of any apparatus permanently attached to it near the forward end. The vertical inclination of the shield was obtained by suspending a plumb-bob close to the diaphragm (which was practically a plane perpendicular to the axis of the shield) and measuring the divergence for a fixed length of suspension. The horizontal divergence was obtained by measuring with long graduated rods from the diaphragm at each side to points set on the iron lining at right angles to the center line. Where the tunnel was on curve, the rod on the outside of the curve was graduated to a scale stretched proportionately to the radii of the two sides of the tunnel, and the index points were set on a radius to the curve. If the shield was pointed on line the rods therefore read alike. The movements of the shield during a shove were varied to correct any excessive divergence as observed by these two devices while the shield was going ahead.

Shield Meetings. — When the shields from opposite sides of the river had approached within about 100 ft. of each other, an 8 in. wrought-iron pipe was jetted and jacked ahead of one of them, approximately on the axis of the tunnel. Although the pipes were not straight, a check on the alignment could be made through them by locating from both ends the tip of an electric

light bulb shoved midway through. For checking grade a ¾ in. water pipe with gauge glasses at both ends was passed through to form a water level. To overcome the slight difference in air pressure acting on the water surfaces in the two shields, a return pipe was cemented to the top of one gauge glass and was led back to the other shield. The cutting edges of the shields when brought together coincided in all cases very closely, the greatest variation at any point being ⅝ in.

In closing, it may be of interest to show the discrepancies which occurred at the meeting of the lines produced from the various shafts. These discrepancies were as follows:

	Alignment.	Grade.	Distance.	Length on Tangent.	Length on Curve.	Total Length
East Avenue to Front Street, Long Island City.						
Line A.	+.03	—.009	+.09	868	1086	1954
Line B.	+.01	—.013	+.065	852	1112	1964
Line C.	+.06	—.020	+.05	949	1033	1982
Line D.	+.01	—.013	+.02	940	1052	1992
Front Street, Long Island City, to First Avenue, Manhattan.						
Line A.	+.03	—.017	—.08	3671	269	3940
Line B.	+.016	—.015	—.08	3629	314	3943
Line C.	+.01	—.034	—.09	3709	245	3954
Line D.	+.03	—.031	+.05	3671	285	3956
First Avenue to Intermediate Shaft, Manhattan.						
Lines A & B.	—.033	—.013	+.087	1715	1069	2784
Lines C & D.	+.031	—.028	—.132	1759	1208	2967
Intermediate Shaft to West Shaft, Manhattan.						
Lines A & B.	+.003	—.037	—.080	2105	0	2105
Lines C & D.	—.010	.000	—.080	1992	0	1992

In the above table all dimensions are in feet, and distances in the tunnel were careful hand measurements.

+ means that the line produced from the easterly shaft was:
For alignment, north of the line from the westerly shaft.
For grade, above the line from the westerly shaft.
For distance, overlapping the line from the westerly shaft.

REVETMENTS ALONG THE RIO GRANDE

BY GEORGE A. McKAY, '08

Rivers that flow for a considerable part of their length through level country have cut for themselves, and follow, courses that are best described by the word "meandering." These courses have been determined, at first, by natural features, as the water has sought its own level. In some sections of our country, such as New England, or wherever the remains of the glacial period are equally in evidence, a course once determined is not liable to change. Even the annual spring freshet, with its battering ram of floating ice, effects little erosion against the rock-protected or gravel-lined banks, such as restrain the Hudson or the Connecticut.

But such is not the case with rivers like the Mississippi or the Rio Grande. Both of these streams, especially as they approach their deltas, are carrying in suspension large quantities of sediment or silt: finely divided particles which have been torn loose from easily eroded alluvial banks. Even under normal low-water conditions, these streams are continually cutting into their banks somewhere. This is evident from their muddy appearance at all times. But at low water, the cutting of the banks, and its attendant change of course, is very gradual. It is in times of high water that damage is done, and a glance at a map will show many shallow crescent-shaped lakes along such a stream. These are old channels which have been abandoned, and which are gradually filling up.

The bottoms of these streams are of a very shifting nature, and a very small obstruction, like a submerged half-buried tree trunk, is enough to cause the main channel to be diverted. If a relatively large obstruction, like a bridge pier, is placed in the stream, some artificial means has to be devised to keep the stream from swinging to one side or to the other at this point. At Harvey, Iowa, where the Rock Island Railroad used to cross the Des Moines River, the course of that stream has changed, and the bridge now stands, carrying the track across a shallow pool, while the main stream has made another bridge necessary.

There is no accepted standard method for restraining such a stream. Nearly every engineer, who has been confronted with this problem of bank protection, has been able to devise a new scheme for effecting this result, but they are always more effective in theory than in practise. The government has spent great sums of money along the Mississippi and the Missouri. Their favorite method has been to weave a mattress of pliable willow twigs, to lay this mattress along the banks, extending from the high-water mark down below low water, and then to weigh this down with rip-rap, and to anchor the mat in place by heavy cables running back to dead men buried in the bank above. This method, like most methods, is expensive to install and to maintain.

The Chicago and Alton Railroad crosses the Missouri River near Glasgow, Mo. That stream, above the bridge, doubles back upon itself, making a horse-shoe bend, and the tendency has been for the river to cut across the narrow part, and to thus leave the railroad's million-dollar bridge high and dry. In fighting to prevent this, that road has spent, in the past ten years on this five-mile stretch of river, a trifle less than $200,000.

So much for the general problem of river-bank protection, or, as it is called, revetment work. The kind of revetment that will be described in this paper is a scheme which has been devised and used, with more or less success, by the Mexican Government along its boundary stream, the Rio Grande. Some of it has just been installed near Brownsville, Texas, where an international bridge is being built by the St. Louis, Brownsville & Mexico Railroad, a part of the Frisco System.

The bridge at Brownsville has three of its piers in the bed of the river. These will contract the channel considerably, and greatly increase the tendency of the stream to scour at this point. The object of the revetment here, then, is to keep the river, where the bridge crosses, from widening, and from possibly undermining the two shore piers, each of which is about 40 feet back from the present banks. The revetment extends for a distance of 400 feet on each bank; 250 feet of this is on the up-stream side of the bridge, and 150 feet below it. The plan, in outline, is to provide a tough and durable lining which

will offer the least resistance to the passage of the stream as it flows and, at the same time, the greatest resistance to the scouring action of the stream.

The revetment consists of a woven mat, put in place during low water on a bank, trimmed to a uniform slope, kept in place by being weighted heavily with rip-rap, and, further, kept from being torn away by anchoring cables, carried back over the top of the bank, and fastened to buried logs.

The mat is made up of facines, or bundles of brush. Quoting from the specifications: "Brush facines of huisache or mesquite made up in bundles 30 feet and 40 feet long, about 12 to 15 inches in diameter; brush alternately towards the middle and ends of the bundle. Must be well compressed, and tied with No. 10 galvanized wire every 2 feet." The brush chosen for this work was "huisache," a low-growing thorn-bearing brush. It is plentiful in this part of Texas, and is an extremely tough and durable, as well as heavy, wood, though mean to handle on account of its very sharp and plentiful thorns. This brush was cut in lengths averaging about seven feet, and hauled, by ox teams, to the edge of the bank. Here it was made into facines. In making these, the brush was laid on the ground, as required in the specifications, not all of the butts pointing the same way, and bound with No. 10 wire, which is the ordinary telephone size. The bundles were compressed by encircling them with ropes, and twisting these tight with short sticks. The wire was wound spirally along the length of the bundles, to keep them from pulling apart in handling and laying. Enough of these facines were made for the entire mat, and piled, convenient to the edge of the river.

When the river was at its lowest stage, the bank, for 400 feet on each side, was graded by pick and shovel to a 2 to 1 slope. All irregularities in the bank were cut away, or filled in, and a straight and uniform slope was obtained. Of the 400 feet, 250 were above the bridge, so as to prevent the water from working in under the mattress, and undermining it.

After the bank was graded, the facines were laid in place, and woven into a mat. It was not feasible to weave the entire 400 feet at once, so it was done in 30-foot sections. As the

bottom of the mat was to be in the stream, the facines were laid farther up the bank, out of the water, so that the laborers could do most of their work on dry land. But in order that the 30-foot sections could be put in place, down in the water, after weaving, they were laid on skids, with cross planks, so that they could be pulled down the slope, and later the skids removed.

First a row of facines was laid, facines being 20 inches on centers, and lying perpendicular to the stream. These were each 40 feet long. Then on top of these, running parallel to the river, was laid another course of facines, each of these being 30 feet long. But this top row was spaced 4 feet apart. Then the process of weaving began. The top facines were tightly fastened to the lower at as many points as seemed necessary, using No. 10 wire. Then ⅜-inch galvanized wire cable was used to further bind the facines into a mat; these running over and under the upper course of facines. When one 30-foot section was woven, it was easily pulled down, sliding on the skids into the water, but in this operation the laborers had to get into the water ahead of it.

Then came the weighting down of the mattress. As no stone could be obtained within several hundred miles, it was necessary to use some other form of ballast which would be cheaper. For this purpose burlap sacks were filled with a poor grade of gravel concrete, mixed 9 parts gravel to one of cement, and these were used in place of rip-rap. These sacks, when empty, were about 18 inches by 36, and were filled half full and allowed to set, flattened out, before being used. About 7,000 of these bags were used on each side of the river.

The elevation of the top of the bank is 40. The elevation of low water is 28. These mats were pulled down the slope until their tops were at about elevation 34. That means that about half of the mat, or 20 feet of it, is in the water, and the remainder, 20 feet, reaches from the water to elevation 34. The bags of concrete, placed on the mat, were laid in between the top course of facines, and are kept by these from sliding down into the water. Above the mat, from elevation 34 to 40, the bank is paved with these concrete bags, laid flat, and side by side, as close as they can be laid.

Each 30-foot section is anchored back by $\frac{3}{8}$-inch cables, running back over the brow of the bank, and fastened to a log, buried about 30 feet from the edge. Each 30-foot section, as it was laid, and pulled into place, was fastened to its neighbor, so that the result of the whole is one compact mat, 400 feet long.

Such mats as the one described above have been laid, with fair success, along the Rio Grande. They are pliable, and if the river starts to wash in under them, the weight causes them to sink with the bank, and always to lie close to it, and to prevent further scouring. The limit, of course, to this sinking is when the mattress becomes so nearly perpendicular that the ballast slides off. Then the mat will float up and lose its value, and will soon be torn away by drift, coming down in the next time of high water.

This revetment was put in place by the Foundation Company of 115 Broadway, New York, as a part of their work of constructing the substructure for the bridge between Brownsville and the Mexican city of Matamoros. Some of the features of this foundation work will be described in a later issue of this JOURNAL.

HARVARD ENGINEERING JOURNAL

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The JOURNAL wishes to express its sincere appreciation of the hearty support of the staff of the department and its contributors, and ventures to hope that it will increase in value not only to the present and past members of the University, but also to the profession at large. Any contributions or suggestions which will aid in accomplishing this result will be welcomed by the Editor.

ANNUAL MEETING OF THE ASSOCIATION OF HARVARD ENGINEERS

The third annual meeting was called to order by the president, Mr. G. S. Rice, at 6 P.M., March 12, in the Trophy Room of the Harvard Union. About twenty-five members were present.

The report of the secretary-treasurer was read and accepted.

The election of Mr. Robert Ridgway as honorary member was confirmed.

The following amendment to the Constitution, as given in the call for the meeting, was adopted:

To add to Article VII a fifth section, as follows:

> "Ex-presidents of the Association shall continue members of the Council for three years from the date of expiration of their term of office."

On motion of Mr. Worcester, it was voted that it was the sense of the meeting that the Council should consider an increase in the membership dues.

The next business of the meeting was the election of officers. The results were as follows:

President:

Bernard R. Green, S.B., '64.
Superintendent, Buildings and Grounds, Library of Congress, Washington, D. C.

Vice-Presidents:

Charles P. Steinmetz, A.M., h. '02.
Consulting Engineer, General Electric Co.; Professor of Electrical Engineering, Union University, Schenectady, New York.

Francis W. Dean, S.B., '75.
Mill Engineer and Architect, 53 State St., Boston, Mass.

Benjamin B. Thayer, C.E., '85.
President, Anaconda Copper Mining Co., New York City.

Secretary-Treasurer:

F. Lowell Kennedy, A.B., '92; S.B., '98.
Assistant Professor of Drawing and Machine Design, Harvard University.

Members of Council for three years:

Asa W. Billings, A.B., '95; A.M., '96.
Engineering Manager, J. G. White & Co., Inc., New York City.

Lewis W. Johnson, A.B., '87; C.E., '88.
Professor of Civil Engineering, Harvard University.

A vote of thanks to the retiring president, Mr. G. S. Rice, was then passed.

On motion, it was voted to adjourn.

An account of the joint dinner with the Engineering Society, which followed this meeting, will be found elsewhere in this issue.

A new list of the members of the Association of Harvard Engineers, with a copy of the revised Constitution, will be issued as a supplement to the next issue of the JOURNAL.

HARVARD ENGINEERING SOCIETY OF NEW YORK

The third annual dinner of the Society was held on February 25 at the Harvard Club. President Lowell made the principal address of the evening, and spoke in reference to the work of the Graduate School of Applied Science and its relation to the work of the University as a whole. Professor Hollis in his speech mentioned the benefits derived from the "Student Loan Fund" subscribed by members of this Society, for the purpose of assisting needy students to meet the requirements of the summer courses in engineering.

The other speakers were Mr. John Hays Hammond and Mr. John C. Montgomery. Mr. Benjamin B. Thayer, president of the Society, acted as toast-master for the evening. The following guests and members were present at the dinner:

President Lowell, Prof. I. N. Hollis, J. H. Hammond, J. C. Montgomery, Captain W. J. Baxter, U. S. N., Prof. W. C. Sabine, Prof. G. F. Swain, Prof. H. L. Smyth, Prof. A. E. Kennelly, Prof. H. J. Hughes, B. B. Thayer '85, J. R. McArthur '85, G. S. Rice '70, F. Remington '87, H. Jennings '77, Prof. W. H. Burr, H. J. Alexander '00, C. E. Baldwin '99, R. C. Barnard '02, J. M. Betton '71, L. W. Bickley '04, A. W. K. Billings '95, C. H. Baker '02, R. Bedford, E. A. S. Clarke '84, C. F. Quincy, G. S. Curtis '92, S. Cunningham, Jr. '01, J. Camprubi, E. G. Davis '98, F. W.

Daggett '99, W. Delano '73, A. Durant '03, F. H. Davol, Jr. '03, D. G. Edwards '03, K. B. Emerson '02, C. M. Eveleth '96, J. H. Fennessy '93, A. H. Fox '02, H. C. Fox '94, H. H. Fox, A. D. Flinn, C. F. Frothingham, F. L. Gilman '95, R. Greenlaw '02, W. S. Gifford '05, C. Gilman '04, F. N. Goble, B. R. Green '63, H. S. Hyde, W. L. Hanavan '03, H. M. Hale '04, W. Hauck '96, J. R. Healy '97, J. S. Hildreth, Jr. '93, C. Herschel '60, J. P. Hogan '03, C. M. Holland '06, S. U. Hopkins '97, W. A. Hedrick '05, J. G. Hackley '01, G. A. E. Irving, F. L. Jones '02, A. C. Jackson '88, M. King '04, J. M. Levine '06, J. P. Locke '00, Wm. Low '05, F. Lyman '74, F. Mason '96, M. F. McAlpin '97, W. Meadowcroft '01, P. Mulock '03, E. Q. Moses '02, H. E. Mead '03, E. Nye, F. A. Nelson '04, A. J. Pates '04, J. C. R. Palmer '04, C. P. Perin '83, N. B. Pope '02, F. Pope '01, H. W. Purcell '05, R. A. F. Penrose, H. Rawson '01, R. Ridgway, F. D. Robinson '99, L. Rome '08, M. H. Ryan '99, J. F. Sanborn '99, T. B. Shertzer '99, C. W. Stark '03, W. F. Stevenson '97, C. Seaver '02, W. R. Soren '93, C. L. Slocum '99, E. L. Sprague, Jr. '03, E. B. Tewksbury '99, R. K. Tomlin, Jr. '07, N. A. Thayer, D. L. Turner, J. W. Smith, J. C. Wait, C. Wilson '94, N. T. Weitzel '04, H. W. Weitzel '05.

The next regular meeting will be held April 15. An excursion will be made in the afternoon to the new Municipal Building now under construction. Special attention will be paid to the foundation work, which is being constructed by the Foundation Co.

In the evening there will be a stereopticon lecture on general foundation work, given by Mr. Franklin Remington, past president of the Society.

The Society has appointed a committee to raise sufficient money to make a substantial addition to the Student's Loan Fund, which now amounts to $600, to fulfill one of the principal objects of the Society, which is to aid and encourage in every way the younger Harvard men interested in engineering.

The money from this fund is lent to students intending to enter the professions of Civil, Mechanical, and Electrical Engineering, or Mining and Metallurgy, to facilitate their taking the prescribed summer courses, on application to the Dean of the Graduate School of Applied Science.

HARVARD ENGINEERING SOCIETY

A regular meeting was held February 25 in Pierce 110. Mr. J. W. Rollins, of the firm of Holbrook, Cabot & Rollins, Corporation, gave an illustrated lecture on "Foundations." Mr. Rollins described the different types of foundations in use, with special reference to the open and pneumatic caisson, and crib foundation. The speaker also touched upon temporary and permanent dams, and masonry arches, illustrating each subject with appropriate views. He also gave several interesting facts concerning the placing and use of concrete.

After the meeting, refreshments were served and a social half-hour was enjoyed.

GEO. W. LEWIS, *Secretary.*

The fourth regular meeting was held on March 11 in Pierce 110. Mr. Herbert M. Hale, '04, gave an illustrated lecture on "Stringing the Cables of the Manhattan Suspension Bridge." Mr. Hale introduced his subject by a historical sketch of the development of bridges in general, with special reference to the suspension bridge. He described, in detail, the method of stringing the cables by carrying the individual wires, of which the cables are constructed, from tower to tower; how the individual wires were made into strands, and the strands wound circumferentially into cables. Numerous other details in regard to the construction of the bridge were described and illustrated.

The meeting was open to the University.

GEO. W. LEWIS, *Secretary.*

HARVARD ELECTRICAL CLUB

The third meeting of the year was held in the Trophy Room of the Union January 19. Mr. John W. Corning, the Electrical Engineer of the Boston Elevated Railway Company, spoke on "Operating Features of the Boston Elevated System." Mr. Corning pointed out on a large map the territory covered by the company's lines, and the location of the various power plants. He then showed by means of large diagrams the growth of the company, the distribution of the load for 24 hours and for 365 days, the relation between temperature and station output, the recent improvements made in smooth starting of cars, the working of the magnetic switches, and many other things of intense practical interest.

W. P. SHEPPARD, *President.*

The fourth meeting of the year was held in Pierce 202 on March 15. Mr. J. F. Vaughan, '95, of the Stone & Webster Engineering Corporation, spoke on the subject of "Hydro-Electric Plants." Mr. Vaughan explained the method used in estimating the amount of rainfall and the size of storage basin necessary; the general character of watersheds, and the elements necessary for a successful storage basin. By the use of the reflectoscope and pictures he described the process of changing water into electrical energy, and its distribution through high-tension alternating current systems.

Refreshments were served after the general meeting.

The former secretary of the club, Mr. C. L. Nourse, having left college, the club voted that the president appoint a member to fill the vacancy.

G. L. Atkins, *Secretary.*

HARVARD CIVIL CLUB

A regular meeting was held December 12, 1909, in Pierce 110. Mr. H. U. Ransom, M.C.E. '09, talked informally about the Cambridge subway. He described tthe method of retaining earth during excavation by means of chisel-pointed timbers, and the operation of lifting earth from the bottom of a deep cut, from man to man. Sketches on the blackboard illustrated the system of drains, three running parallel under the length of the tunnel. Waterproofing consists of covering a six-inch layer of concrete with four layers of roofing felt interlaid with hot tar. The relative economy of transporting concrete from a large mixing station against using portable mixers was taken up.

A. R. Arellano, *Secretary.*

HARVARD AERONAUTICAL SOCIETY

The Journal takes great pleasure in publishing the following brief account of the organization and activities of this new society, and will continue its record in future issues.

Mr. James V. Martin, Sp., a student of practical aeronautics under Mr. Herring and other prominent aviators, conceived, early in the fall, the idea of a society for the promotion of theoretical and practical study of the new science at the University. Through his efforts interest was aroused, and a plan and consti-

tution drawn up. On November 11 an enthusiastic meeting was held for organization in the Union, and 225 men signed for charter membership. The constitution was adopted, and the following officers elected for the year: President, Prof. Abbot Lawrence Rotch; vice-president, Hugh Nawn, '10; secretary, Edwin C. Brown, '12; treasurer, Arthur Sweetser, '11; Board of Directors: R. L. Groves '10, T. H. McKittrick '11, J. V. Martin Sp., W. B. Strong '10, H. de Windt '12; Advisory Board: Professors F. L. Kennedy, L. S. Marks, W. H. Pickering.

On November 29, Mr. A. A. Merrill delivered the first of the course of lectures, selecting as his subject "The Principles of

Mechanical Flight." This lecture was illustrated, and was held in Fogg Lecture Hall. A cinematographic exhibit, showing aeroplanes starting, in flight, and also balloons filling and casting loose, was given in Brattle Hall on December 10; this was probably the most complete of its kind yet shown in the United States. On January 18, Prof. A. L. Rotch gave an illustrated lecture in Pierce 110 on "The Physics of the Atmosphere as Related to Aeronautics." On January 24, Mr. Martin gave a practical talk in Sever 5 on the construction of aeroplanes and gliders, illustrating the points with drawings and the two models of the Wright and Bleriot machines which the society had purchased. At this meeting members were invited to form a *glider section,*

an *aeroplane section,* and a *motor experiment section.* A. W. Carpenter, '12, who had already done some gliding work the previous summer, was put in charge of the glider section, and construction was begun on January 28. By the date of opening of the Aero Show in Mechanics Building, Boston, on February 16, the society was able to exhibit not only its models and drawings of the aeroplane, but also the glider. A booth was maintained as headquarters for the members, and a pamphlet setting forth the plans for the coming season, with a brief description of the aeroplane to be constructed, and its novel features for attaining fore-and-aft and transverse stability, was printed and distributed. In the meantime the society had incorporated, and had affiliated with the Aero Club of America, thus giving its members the privileges of competing in meets both here and abroad; it had also established an Aero Library on special shelves in the Gore Hall Reading Room, consisting of most of the late books on aviation, and current periodicals devoted to that subject. On March 25, Prof. I. N. Hollis gave an illustrated lecture in Pierce 110 on the "Movements of Bodies in the Air."

The aeroplane section has been working for some time on the fittings for the large machine, and the contracts for the laminated wood used in its construction were placed some time ago, so that it is expected that all parts will be ready for assembling early this month. The motor experiment section is about to begin tests on an engine in the laboratory. The glider, which is wholly completed, will be tried out in the field as soon as the weather permits.

Provision for both undergraduate and graduate members was made in the constitution, and the membership list is already over 360. Those interested should communicate with the secretary, 27 Holyoke Street, Cambridge.

JOINT ANNUAL DINNER OF THE ASSOCIATION OF HARVARD ENGINEERS AND THE HARVARD ENGINEERING SOCIETY.

The third annual dinner of the Association and the Engineering Society, which was also the twelfth annual dinner of the Society, was held in the Assembly Room of the Union the evening of March 12. There were 112 men present.

Mr. George S. Rice, S.B. '70, president of the Association and member of the Public Service Commission of New York, acted as toastmaster, and introduced as the first speaker Mr. Charles

P. Steinmetz, h. '02, Consulting Engineer of the General Electric Company and Professor of Electrical Engineering at Union University, Schenectady, New York. Mr. Steinmetz spoke in a very interesting manner on "The Life in General of an Engineer," giving illustrations from his own experience in preparing for such work. He had decided on an academic career as a university professor in Germany, and was about to take his doctor's degree when, on account of political affiliations with the Socialists, he was forced to leave the country and go to Switzerland. From there he came to the United States and took up his present work. His training had been anything but preparatory to scientific engineering, having comprised mostly classical and philosophical subjects, yet to this very fact Mr. Steinmetz lays the cause of his present success. He emphasized the necessity of engineers guarding against becoming mere skilled laborers; specialists can easily be obtained for hire, but men with skill as well as a knowledge of human nature cannot so easily be secured. Accuracy and facts as a foundation, are absolutely necessary in the engineering profession, but a thorough knowledge of things outside tthe engineering curriculum is the key to the success of the foremost engineers of the country.

Mr. C. W. Baker, '84, editor of the *Engineering News,* continued the theme of Mr. Steinmetz' remarks by showing how well Harvard engineers are able to meet such requirements. The objection of some men to a liberal education before specializing in a profession is a sordid reckoning of dollars and cents. The breadth of mind and the power for good, which a Harvard engineer receives from his college training before entering the scientific school, is providing that calibre of men, which is most needed in the world to-day. The fact that a man may have the special training, which Harvard University offers her engineering students, may have little effect in securing the first position, but it will tell in the long run.

Hugh Nawn, '10, president of the Harvard Engineering Society, spoke of the present flourishing condition of the society.

George W. Lewis, '10, editor of the JOURNAL last year, outlined the position of the paper at the present time.

The following members of both organizations were present:

C. P. Steinmetz, h.'02	Louis Arnold, '57
Prof. H. E. Clifford	Bernard R. Green, '63
Prof. G. F. Swain	Geo. S. Rice, '70
Prof. C. A. Adams	F. W. Dean, '75

J. R. Worcester, '82
A. C. Lane, '83
Henry Bartlett, '85
Charles W. Baker, '86
Prof. L. J. Johnson, '87
P. M. Hammett, '88
Prof. F. L. Kennedy, '92

Class of '95

P. W. Davis
F. E. Frothingham
Prof. E. V. Huntington
H. W. Smith
W. H. Herschel, '96
C. S. Dow, '97
E. M. Moses, '97
F. V. Edgell, '98
J. H. Libbey, '98
John Ware, '99
N. R. Willard, '00
C. H. Dutton, '01
V. M. Frost, '02

Class of '03

H. M. Boylston
Geo. Gibbs, Jr.
J. G. Patterson

Class of '04

Chas. Gilman
H. M. Hale
J. P. Hogan
A. H. Paige
W. M. Stone

Class of '05

D. L. Furness
W. St. C. Jones
P. M. Patterson

Class of '06

S. R. Crosse
W. Danielson
J. R. Nichols

Class of '07

E. F. Burnham
Chas. E. Devonshire
H. L. Lincoln
H. U. Ransom

Class of '08

W. H. Durfee
A. Fraser Campbell
G. James
H. A. Richardson
M. T. Rogers
E. B. Smith
J. Tyng

Class of '09

F. B. Duveneck
A. B. Green
E. N. Hutchins
G. F. Williams

Class of '10

H. A. Allen
I. A. Blake
G. S. Bohlin
R. W. Coburn
W. B. Durant, Jr.
G. W. French, Jr.
H. E. Harwood
E. A. Healy
L. W. Hickey
J. Humphry, Jr.
S. S. Kent
C. S. Lee
Geo. W. Lewis
Chas. A. Linehan
P. A. Merriam
H. Nawn
W. Ordway
C. R. Safford
W. B. Strong
A. M. Sweeney
B. Wheelwright
E. S. Wolston
L. Wulsin

Class of '11

R. Brunel
J. F. Gowen
H. S. Knauer
P. C. Nash
Geo. F. Owen
S. G. Rich
N. S. Smith, Jr.
J. M. Taylor

Class of '12

F. P. Donovan
G. D. Edwards
F. W. Hill
H. S. Hegarty
W. S. Hood
T. R. Kendall
S. S. Kingman
E. S. Lancaster
H. A. Libbey
F. H. Morrison
C. M. Ramsey
H. N. Witt
R. B. Wolverton

Class of '13

H. V. Bail
Geo. E. Fahys, Jr.
F. W. Harvey
H. S. Johnson
J. T. Remey
L. N. C. Smith, Unc.

Graduate School

M. R. Wolfard, 2G.
J. C. Barnes, 1G.
R. H. Eurich, 1G.
T. C. Ma, 1G.
L. W. Perrin, 1G.
H. G. Venemann, 1G.

GRADUATE NOTES

(*On account of the many inquiries as to the whereabouts of graduates of the department, it is hoped that the editor will be notified of changes of address or occupation. Such notes will appear promptly in this column.*)

F. A. Alden, '07, is chief engineer with McLean & Cousens, 204 Purchase St., Boston.

H. K. Alden, '06, is with the Boston & Albany Construction, East Boston. Address: 25 Chestnut St., Wakefield, Mass.

H. B. Barney, '08, is at 34 Perrin St., Roxbury, Mass.

Lee Barrol, '09, address 684 Salem Ave., Elizabeth, N. J.

W. M. Bird, '08, address 27 Otis St., Newtonville, Mass.

S. T. Bittenbender '07, is with the Argentine Quebracho Co., Tartago, Argentine Republic; or care of T. H. Christin, 115 High St., Boston.

C. E. Chace, '07, is with the Board of Water Supply, New York. Address: 24 Porterfield Pl., Freeport, Long Island, N. Y.

E. N. Davis, '09, is in the testing department, General Electric Co., Schenectady, N. Y.

G. E. Doyen, '07, is Superintendent of Pavement Construction with Hastings Pavement Co., Room 1827, 25 Broad St., New York City.

J. R. Finlay, '91, Mining Engineer, has accepted the position of General Manager of the Goldfield Consolidated Mines, Goldfield, Nevada.

E. E. Ford, '08, is with the Turner Construction Co., New York City.

H. P. Forte, '07, is with the Wm. Underwood Co., 52 Fulton St., Boston.

E. S. Fuller, '08, is Junior Engineer with the United States Geological Survey, Box 972, Salt Lake City, Utah.

W. Gaskill, '09, is in the testing department, General Electric Co., Schenectady, N. Y.

Francis L. Gilman, '95, a member of the Executive Committee of the Harvard Engineering Society of New York, has accepted the position of General Manager of the Missouri & Kansas Telephone Co., Kansas City, Mo.

N. K. Hartford, '09, address 12 Parker St., Watertown, Mass.

O. W. Hartwell, '08, is a Junior Engineer with the United States Geological Survey, Box 972, Salt Lake City, Utah.

L. W. Hayes, '07, is with the Cornell Art Metal Co., Ilion, N. Y.

A. G. Hentz, '09, address 1808 Beacon St., Brookline, Mass.

J. P. Hogan, '04, is Assistant Engineer with the Board of Water Supply, High Falls, N. Y.

G. A. Irving, Jr., '07, Electrical Engineer, address 102 Henderson Ave., New Brighton, N. Y.

G. James, '08, student at M. I. T., address 33 Buckminster Rd., Brookline, Mass.

L. R. Jenkins, '07, address Mamouth, Cal.

C. W. Killam, '07, Ass't Prof. Arch. Constr., Harvard University. Address: 20 Walker St., Cambridge, Mass.

H. L. Lincoln, '07, is in the Power & Mining Dept., General Electric Co., Schenectady, N. Y.

H. S. McDewell, '07, is a student apprentice. Address: 6206 Greenfield Ave., West Allis, N. Y.

Geo. A. McKay, '08, is with the Foundation Co., on Construction Work, at Brownsville, Texas.

N. C. Mills, Sp. '97-'99, is a designing engineer with the Canadian General Electric Co., at Peterboro, Ontario, Can.

C. E. Nichols, '07, address 811 E. Denny Way, Seattle, Wash.

C. C. Pope, '08, is soliciting for Stone & Webster, and at present is located with the Key West Electric Co., Key West, Fla.

J. V. Quinlan, '07, is with Edwin C. Lewis, Inc., Electrical Engineers & Contractors, Boston. Address: 52 High St., Brookline, Mass.

M. T. Rogers, '08, is Assistant Engineer with A. T. Safford. Address: 63 Fifth Ave., New York City.

C. A. Sargeant, '07, address Maple Creek, Saskatchewan, Can.
R. Sickles, '07, Civil Engineer, 122 West Ave., Lockport, N. Y.
W. St. George, '07, is with M. B. Foster Electric Co., 436 Main St., Waltham, Mass.
E. B. Smith, '08, address Box 122, South Framingham, Mass.
R. D. Thomson, '07, address 72 Buell St., Burlington, Vt.
R. K. Tomlin, '07, address 41 Waverly St., Brookline, Mass.
J. J. Tracey, '07, address 3535 Euclid Ave., Cleveland, Ohio.
G. F. Williams, '09, address 4 Beech St., So. Framingham, Mass.
J. M. Wiseman, Sp. '08, address 4 Gore St., Cambridge, Mass.

MISCELLANEOUS NOTES

Arthur Edwin Norton was appointed Assistant Professor of Mechanical Drawing, at the meeting of the President and Fellows on January 17, for five years from September 1, 1910. (*Consent given by the Board of Overseers, February 23.*) Mr. Norton spent last year with the Allis Chalmers Company, of Milwaukee, in the department of Pumping Engines and Hydraulic Turbines.

Ph.B. (Brown). 1900. Instructor in Mechanical Drawing, 1900-01, Drexel Institute, Philadelphia, Pa.; Instructor in Mechanical Drawing, 1901-05, Instructor in Mathematics, 1904-05, Instructor in Mechanical Drawing and Descriptive Geometry, 1905-10, Harvard University.

Among *recent* publications by members of the staff are:

"Tables and Diagrams of the Thermal Properties of Saturated and Superheated Steam," by Prof. L. S. Marks and Dr. H. N. Davis. Published by Longmans, Green & Co.

"Engineering as a Profession and its Relation to the American Association for the Advancement of Science," by Prof. G. F. Swain. Address as Retiring Vice-President, Section D, American Association for the Advancement of Science. *Science* 31 : 81-93.

"Training Men for Industrial Pursuits and their Advancement in Science," by Prof. I. N. Hollis. Founders' Day Address, November 29, 1909, Clarkson Memorial School of Technology, Potsdam, N. Y. *Clarkson Bulletin,* 7: 1-18. January, 1910.

"On the Modifications in Herring's Laws of Furnace Electrodes Introduced by Including Variations in Electric and Thermal Resistivity," by Prof. A. E. Kennelly. *Proceedings of the American Institute of Electrical Engineers,* 29: 267-283. March, 1910.

"Telegraph-Cable Repairing on a Christmas Day," by Prof. A. E. Kennelly. *Popular Electricity,* 2: 779-782. April, 1910.

Among the *researches* now going on are the following:

The construction and investigation of a new type of oil engine with water injection, by M. R. Wolford.

An investigation on the causes, and the possible prevention, of clinkering in boiler furnaces, by E. Daland.

An investigation carried on at the larger power plants of Cambridge to determine the causes and means of prevention of smoke, by H. T. Hicks and N. M. Osborne.

The 50-ton ammonia absorption refrigerating plant at the Power Plant of the Harvard Medical School is being fitted up very thoroughly as an experimental plant. It will prove a most valuable addition to the laboratory equipment, both for instruction and research. It is intended to fit it up more completely than has ever been done on a plant of its kind. The researches which are to be carried out immediately will be done by G. A. Young and H. G. Veneman, under the direction of Professor Marks.

Prof. L. J. Johnson spoke before the Boston Young Men's Christian Union on January 15, on "Concrete Construction as Exemplified in the Harvard Stadium and other Modern Structures."

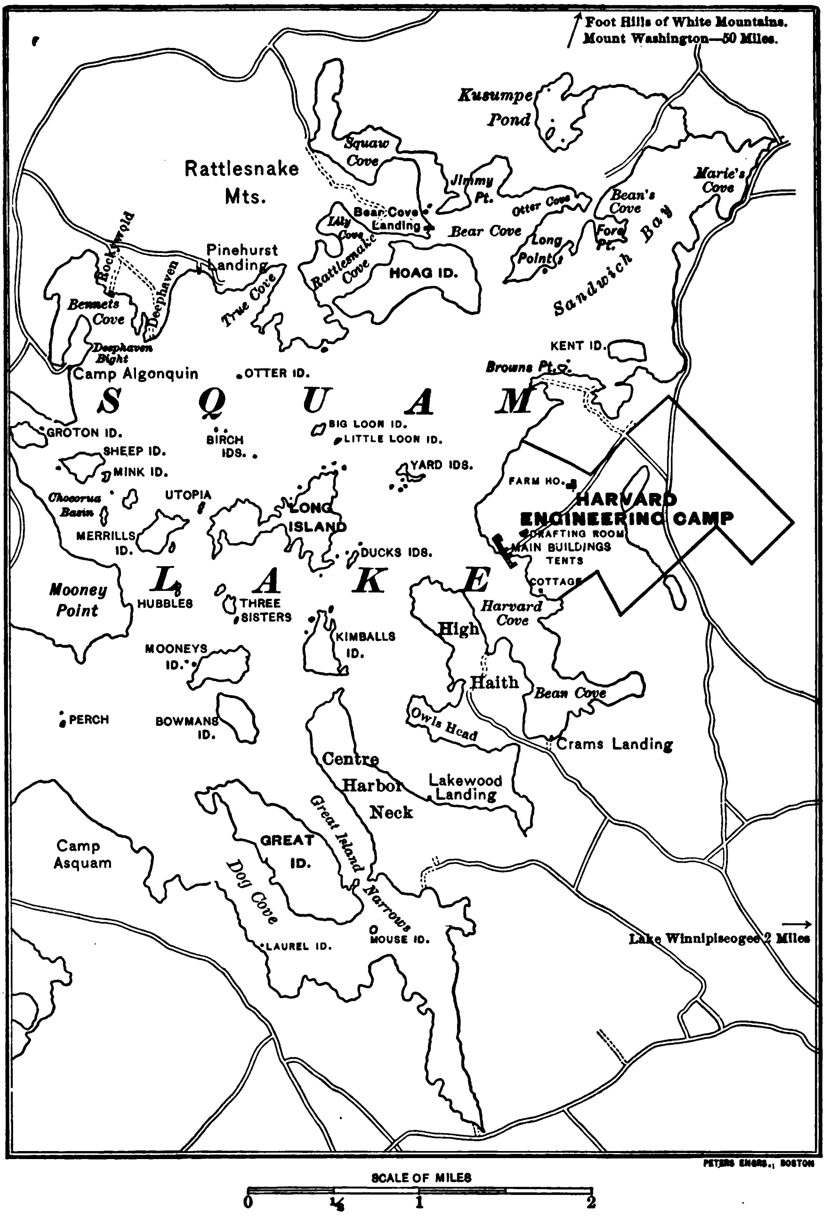
Mr. Howard Elliot, '81, President of the Great Northern Railway, gave the third of the Union lectures on the professions, choosing as his subject "The Northwest and the Railroads," on February 23.

Mr. W. B. Parsons, engineer of the Cape Cod Canal, spoke on March 17, on "Civil Engineering," concluding the Union lectures on professions for the year.

THE HARVARD ENGINEERING CAMP

The Engineering Camp at Squam Lake, New Hampshire, will open Thursday, June 23, and close Tuesday, September 6. Some information concerning the Camp may be of interest to readers, especially those who are not members of the University. The Camp is a part of the University; and while primarily designed for its members, it is, however, open to students in other institutions, and in general to any man with suitable preparation.

The primary purpose of the Camp is to provide instruction for students of engineering under a system of continuous work



HARVARD UNIVERSITY: LAND AT SQUAM LAKE, N. H., FOR WORK IN SURVEYING, ROAD AND RAILROAD ENGINEERING, ETC., THE SUMMER ENGINEERING CAMP, 700 ACRES

and constant supervision, as nearly as possible reproducing the conditions of practice. The courses provide distinctly professional training for Civil, Mechanical, Electrical, and Mining Engineers, Landscape Architects, Geologists, Foresters, and other technical men.

The work consists of a series of problems which include and illustrate the use of necessary instruments and principles, each problem requiring from one to five days. The students are divided into small squads, each in constant charge of a section assistant. Field books, map, computations, and reports are criticised from the standpoint of the practising engineer. To test the student's progress in acquiring a knowledge of methods and of the mathematics of surveying, frequent written and field tests are given. The arrangement provides a large amount of practice in connection with a thorough grounding in principles.

In addition a similar system of uninterrupted study is applied to certain courses in Elementary Mechanics, which regularly given at Cambridge during the college year, are repeated at the Camp, chiefly for the benefit of men intending to enter the Graduate School of Applied Science; and in many instances deficiencies may thus be met by taking work at the Camp previous to entering the University.

The courses to be given this summer are as follows: A course in the fundamentals of surveying: ENGINEERING 4a, which begins with approximate methods and develops the principles of plane and topographical surveying, with field and office practice in the various kinds of surveys used in engineering work; this course occupies six weeks.

A short course in higher surveying: ENGINEERING 4c, known as Geodetic Surveying. This course lasts three weeks and is planned for men contemplating work requiring a knowledge of the methods of determining absolute position, base line measurements, angle observations, precise and trignometrical levelling; in short, it covers such preliminary notions as may be expected of men entering government survey work. The Camp has secured from the U. S. Geological Survey an experienced topographer for instruction in this course.

Railroad Surveying, ENGINEERING 4d, is a course in applied surveying, and has for its subject the fundamentals of railroad location; and considers such matters as curves, alignment, grades, earthwork and estimates, a knowledge of which is essential not only to those engaged in or contemplating railroad work, but

also to those who, later, may have to do with common roads, canals, river regulation, or drainage and irrigation projects. This course requires five weeks, and is usually taken in the same summer and following ENGINEERING 4a.

A course in Elementary Statics, ENGINEERING 5b, considers this subject with especial reference to a thorough grounding in the fundamental principles, and employs both graphic and algebraic methods. Three weeks are required for this course.

A second course, in Mechanics, ENGINEERING 5e, is devoted to the treatment of Elementary Kinematics and Kinetics. Together with ENGINEERING 5b, this course is a necessary preparation for the courses in Applied Mechanics which are given at Cambridge during term time. Three weeks are required for this course.

One course only may be taken at a time, but in one summer a properly prepared student may take the following courses: 4a and 4d; or 5b, 5e, and 4d; or 5b, 4c, and 4d.

For the courses in surveying, a charge of eleven dollars a week is made, with an additional charge of twenty dollars for ENGINEERING 4a and ENGINEERING 4d in the case of students not members of the University; for ENGINEERING 4c this additional charge is ten dollars. In Elementary Mechanics the charge is forty-eight dollars for the whole course, and there is no additional charge.

Registrations may be filed at 114 Pierce Hall, either by mail or in person. Members of the University are expected to register on or before Wednesday, June 15. Those who have registered and subsequently wish to withdraw, may do so, but in order that they may not be liable for the fee, the notice of withdrawal must be in writing, and received by the Director not later than Wednesday, June 23. Men who, for sufficient cause, have been unable to register earlier, may be received up to the date of opening camp.

It not infrequently happens that men, not members of the University, wish to join the Camp during the course, and this may generally be arranged by special agreement.

The Camp may be reached by way of Ashland, N. H., which is on the Boston & Maine Railroad; from this point the boats of the Asquam Transportation Company connect directly.

The Camp property covers about seven hundred acres of farm and woodland; the topography is varied and well adapted for practice in the many kinds of surveying problems. Its loca-

tion among the foothills of the White Mountains insures an exceptionally healthful summer climate. The water supply is pure, the sanitary conditions are excellent and carefully maintained, and a physician is in constant residence. The students live and work as much as possible out of doors. The sleeping quarters are in large tents accommodating four men each, and are provided with wooden floors and platforms, the living accommodations being based on the expectation that only men in good physical condition will elect these courses.

The offices, lecture rooms, draughting rooms, dining-room for wet weather, and kitchens are in substantial wooden buildings, are lighted by gas, and thoroughly equipped. The instrument equipment is ample and comprehensive, standard types are well represented, and the student has every opportunity to acquire a useful familiarity with almost any instrument he may later be called upon to use.

A special descriptive pamphlet is published each year, and the Director, Professor H. J. Hughes, is ready at any time to furnish any further information that may be desired.

MAY, 1910.

THE OFFICIAL ORGAN OF THE
ASSOCIATION OF HARVARD ENGINEERS

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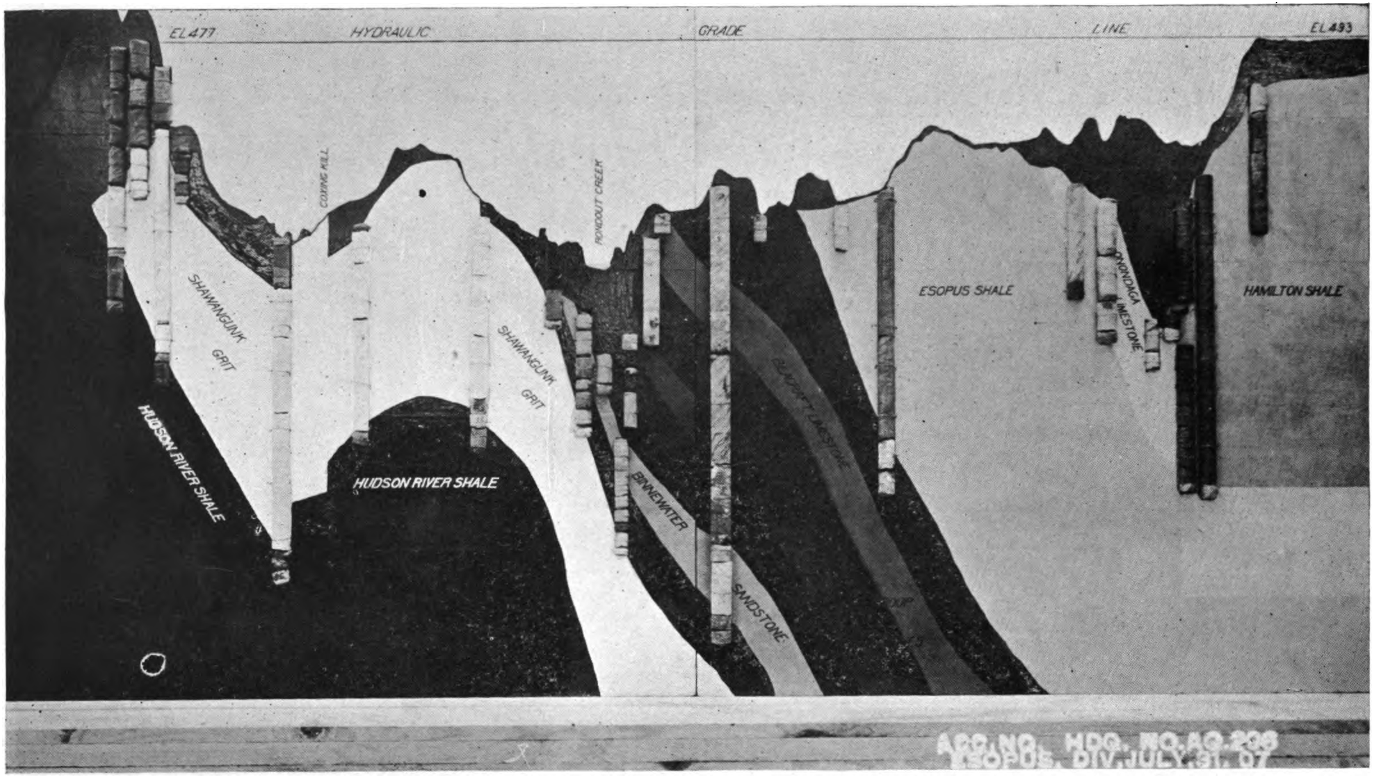

Plate 4.

SECTION ACROSS RONDOUT VALLEY, SHOWING DIFFERENT STRATA AND DIAMOND DRILL CORES IN THEIR PROPER RELATIVE POSITIONS. VERTICAL SCALE—TWENTY TIMES HORIZONTAL.

(*Uses and Methods of Preliminary Borings for Engineering Works, page 64.*)

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USES AND METHODS OF PRELIMINARY BORINGS FOR ENGINEERING WORKS

BY JOHN P. HOGAN, '03

With the growth of a demand for works of a permanent character the use of borings is increasing greatly; and the civil engineer should have enough familiarity with the mechanical details and interpretation of borings to supervise and direct the work, to keep the proper records, and to avoid waste of time and money in ineffectual work. While the present machinery and tools for boring have been developed and have reached their highest efficiency in the commercial development of mines, oil and natural gas wells, etc., in civil engineering work boring is of growing importance in foundation work for dams, locks, docks, bridges and buildings, and in preliminary explorations for tunnels.

Underground explorations are divided naturally into two classes: (1) earth or surface work, and (2) rock work. The former may be done by soundings, test pits, or wash borings, and the latter by some type of rock drilling machinery. The work in prospect may involve only the determination of the character of the material for a short distance below the surface, as in open cuts, trenches, small earth dams, and minor buildings. In such cases soundings or test pits may be used. Again it may be desired to determine conditions to be encountered in earth for considerable depths, as in pile and floating foundations, in deep cuts, or of high earth dams. For this work wash borings,

with or without supplementary test shafts, may be sufficient. Masonry dams, sky-scrapers, and other important structures intended to be founded on solid rock require the positive development of the rock profile or surface. A common mistake is to rely on soundings or wash-borings for this information, but it is impossible to emphasize too strongly the statement that wash-borings give only negative results; *i.e.*, they indicate only that there is no rock within their depth. The wash boring will not penetrate boulders of any size, and the writer has known of boulders or overhanging ledge of from 10 to 16 feet in thickness.

The foundations of a large building furnish a good illustration of the proper use of wash-borings. Where the foundation is to rest on rock a considerable distance below the surface of the ground, one of the most common methods is to sink pneumatic caissons, which are afterwards filled with concrete. The limit of depth for this work is about 100 feet, as the necessary air pressures below this point are too high to permit men to work inside the caissons. Wash borings going down over 100 feet would show that some other method must be adopted. If the wash borings indicated rock nearly 100 feet deep, it would not be wise to count on using pneumatic caissons; unless the borings were extended 10 or 15 feet into the supposed ledge, to prove that it was not a boulder or a layer of very hard material.

The development of the rock profiles of tunnels has not been general enough. There are cases on record where contracts have been let for rock tunnels, and considerable portions of them have proved to be in earth, resulting in great additional expense to the contractor, and necessitating a revision of the contract. Very recently, after an Alpine tunnel, supposed to be located entirely in rock, had penetrated several miles, a gorge, filled with earth, was encountered. Earth and water rushed into the heading, burying over twenty men and filling up 8,000 feet of tunnel, which had to be abandoned. A small amount of boring at critical points might have prevented these difficulties.

The development of rock strata for great depths is frequent in the mines, but has not been common until recently in purely engineering work. One of the important recent examples has been the work done by the Board of Water Supply of the City of New York in the location of the various pressure tunnels of the Catskill Aqueduct. The purpose of this work and the general relation of geology to the location of pressure tunnels was ex-

plained by Mr. James F. Sanborn, '99, in the HARVARD ENGINEERING JOURNAL of June, 1908. In the following pages the writer has attempted to give the results of his observations on the boring work in connection with the Rondout Pressure Tunnel, which involved drilling 137 holes of an aggregate depth of over 22,000 feet:

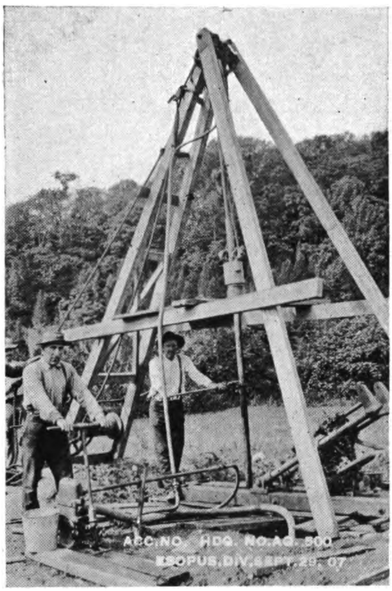


PLATE 1.

SIMPLE TYPE OF HAND WASH RIG.

Drilling naturally divides itself into two parts:

(1) Surface work.

(2) Rock work.

In a glacial country, where coarse gravel and boulders are encountered, the surface work, if of any depth, is usually much slower and more difficult than the rock work.

There are four general types of drilling machines:

(1) Spudding machine or churn drill.

(2) Wash drill.

(3) Diamond drill.

(4) Calyx or shot drill.

Photographs of common types of drills are shown on plates 1, 2, and 3.

The spudding machine depends upon the force of gravity and impact for its progress; grinding up material before it into sludge, which is removed by a sand pump. It is used both in rock and earth, but no record of rock, other than cuttings, is recovered.

The wash drill is used only for surface borings, and depends for its progress on washing, driving, and blasting. It is often used with diamond and shot drills for getting through the surface material. There is a casing and interior wash pipe. Water is forced down through wash pipe and up between wash pipe and casing, and this washes away material below pipe and carries it to surface. Whenever hard material or gravel is encountered a chopping bit is attached to lower end of wash pipe, which is raised and allowed to drop with a churning motion. The cuttings are removed by the water. In case a boulder is encountered that cannot be chopped, dynamite is set off at bottom of hole, either shattering boulder or blowing it out of the way.

The diamond and calyx (shot) drills are both rock drills, and are usually operated with a wash drill attachment. The bits of both consist of annular rings and remove a solid cylindrical core; the former depending on black diamonds or carbons and the latter on hardened steel shot for the cutting agent. The bit in each case is rotated by means of a line of hollow rods, through which a stream of water is kept flowing. Between the rods and the bit is a hollow core barrel, 10 feet long. In the case of the calyx or shot drill no attempt is made to lift cuttings to the top of the hole, as the stream of water necessary would be too strong and would carry away the shot. There is a calyx or hollow receptacle just above the core barrel. The stream of water is just strong enough to carry cuttings into this receptacle, and they are lifted at the same time with the core. The shot are also fed in at will by means of the water. In case of the diamond drill, however, powerful pumps are used, and the cuttings are lifted to the top. The stream of water also serves to keep the bit from overheating by friction.

In case of the calyx drill the core is removed by means of washing sand in between the core and the core barrel until they become fixed. With the diamond drill a spring core lifter is used, which grips the core in the barrel.

Difficulties of Wash Drills

In porous material it is necessary to keep the casing very

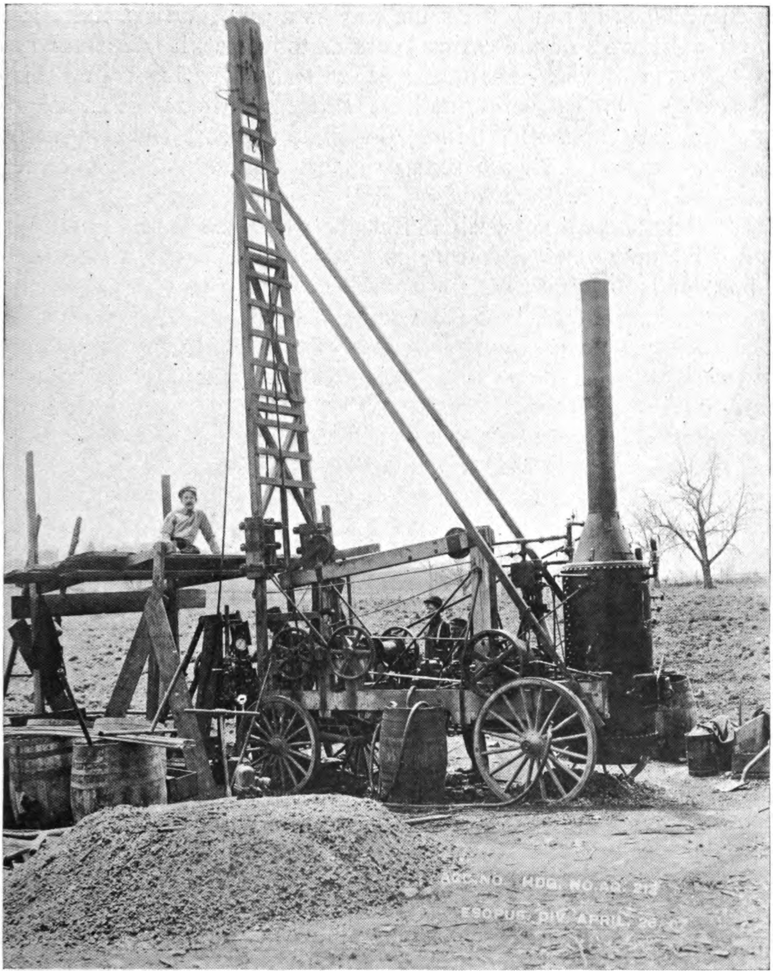


Plate 2.

PORTABLE STEAM WASH RIG WITH SULLIVAN "BADGER" DIAMOND DRILL ATTACHMENT.

close to the end of the wash pipe, or the water will all be lost in the ground instead of returning to the surface with the cut-

tings. In difficult going the wash pipe is forced ahead a few feet, and the casing then is partly driven and partly washed to the same level. The casing is driven by means of a heavy weight or drive block in much the same way as a pile. Where the friction on the sides of the casing becomes too great, it is customary to telescope it with the next smaller size of casing. For this reason deep holes are sometimes started with 12-inch casing and followed up with 10-inch, 8-inch, 6-inch, 4½-inch, 3-inch, and 2-inch; and the wash rods or diamond rods and bit operate inside of the 2-inch casing.

It is important to wash the casing down as far as possible, and drive only when necessary so as to keep it loose; for in case a boulder is encountered, which it is necessary to blast, the casing must be raised 6 to 8 feet, or beyond the effect of the blast. The casing, when being driven, sometimes bends, crumples up, or telescopes at the coupling. While being pulled, it sometimes parts at the couplings. In these cases it is necessary to pull out the entire line of casing and begin over again. If the casing has parted, a tap is used for cutting a new thread in the top of the lower portion so that it can be pulled. Taps are also used for recovering wash and diamond rods when they have parted in the hole. One of the most troublesome accidents is the loss of a chopping bit in the hole, either through breakage of wash pipe or loosening of coupling. The only remedy is to blast the bit out of the way, if possible. The bit usually shows a marked tendency to follow the wash pipe down, and, though repeatedly blasted away, usually lands up sooner or later below the wash pipe and has to be again blown out. Like an undesirable acquaintance it keeps turning up at the most inconvenient times, until finally destroyed by the blasting.

When the casing brings up hard on a boulder or other obstruction, dynamite is let down into the hole by means of the battery wire and exploded with an ordinary blasting battery. Nitro glycerine is used by oil-well drillers, but is very dangerous to handle. In addition, as the wash drill holes are usually pretty well filled with water, the shock of nitro glycerine would split the casing unless packed with 30 or 40 feet of sand, which would have to be washed out of hole after each blast. The trouble with dynamite is the difficulty of setting it off at any great depth. It becomes wet and chilled at a depth of 200 to 300 feet, and the connecting and leading wire joints, unless thoroughly water-

proof, are apt to short circuit. When it is remembered that the operation of blasting requires that the casing be pulled, a very

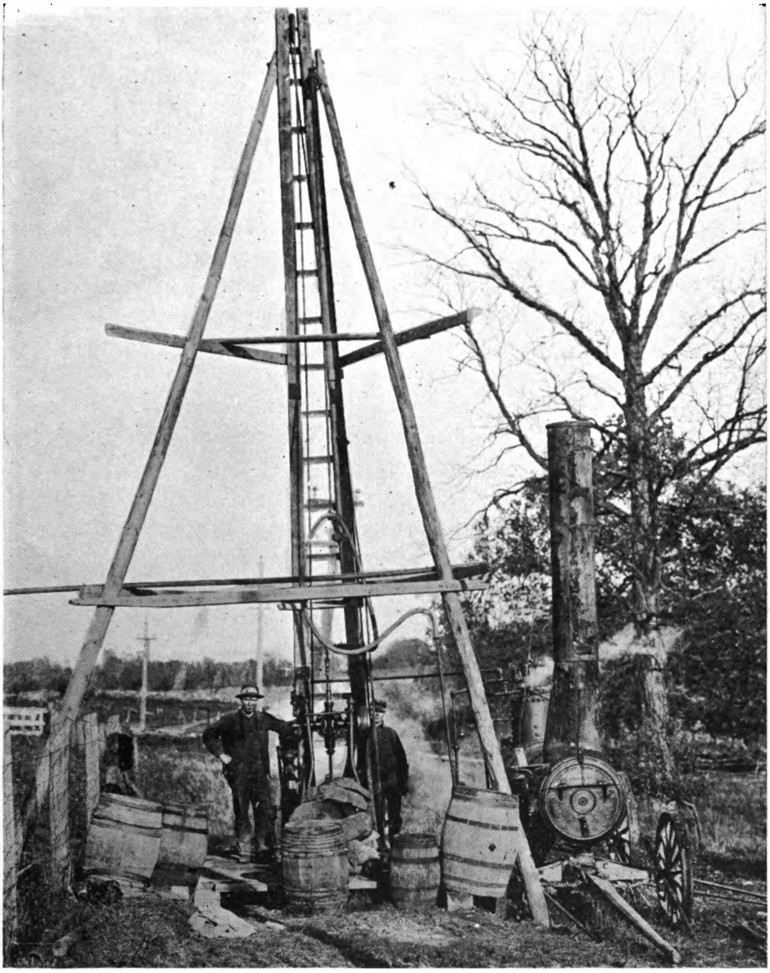


PLATE 4.

LARGE TYPE OF DIAMOND DRILL.

laborous operation if the line be very long, and that it is necessary if a shot fails, to drive casing again and wash out dynamite and tamping, such failure becomes a very serious matter.

In case a large boulder or ledge rock is encountered, any number of shots on top of it will prove useless. A core drill must be used to bore a hole into boulder, so that it will be shattered by blast, or to take enough core from ledge to demonstrate that it is no boulder. For this reason wash drills alone give only negative information unless supplemented by core-boring machines; i.e., they indicate there is no rock for the depth to which they have penetrated, but do not indicate that ledge has been reached.

Sometimes strong artesian flow is encountered in drill holes, causing an eruption of mud and gravel from the top of the pipe. Stones have been forced out, which are apparently larger than the diameter of the casing. Marsh gas will sometimes force large quantities of mud and water for a height of 10 feet above the top of the pipe and a powerful pump is needed to overcome these various troubles.

The chief difficulties of wash borings are caused by large boulders, and a core-drill attachment is necessary to deal properly with these. It is not sufficient, however, to drill a hole through the boulder, for the boulder itself must be shattered to permit the larger casing to follow up the wash rods, or the water will be lost in the hole instead of returning to the surface with the cuttings.

In case of a boulder 10 to 20 feet thick, which it would be impossible to shatter with dynamite, a hole is drilled in the rock, large enough to let the next smaller size of casing through, and casing is continued down to rock. This is very expensive. The smallest casing in which a diamond bit can be operated is the 1⅝-inch flush joint casing. If, through the necessity of frequent telescoping, it is impossible to reach rock with this casing, the hole must be abandoned and started over again with larger casing.

Chief Difficulties in Diamond Drilling

The bit in the diamond drill is an annular ring, set with eight or more black diamonds according to the size. The diamonds for drilling purposes vary in size, usually, from a carat to a carat and a half, and are worth in bulk from $45 to $100 per carat. A good set of stones, well tried and proven, have a much larger value, and a bit set with such stones will vary from $600 to $1,000 in value. To a small contractor the loss of a bit is a calamity, and even to a large one it is a serious misfortune.

The bit and core barrel are fastened on the end of the rods and let down in the hole, additional lengths of rods being added on as required. The usual length of a core barrel is 10 feet, and it is necessary to pull the rods and bit out every time the barrel is filled. To drop the rods when they are being pulled out of a deep hole is one of the worst accidents possible on account of the great weight of the rods. Another serious accident is to have the bit stuck in the hole. This happens most frequently in soft or caving rock, and it is sometimes necessary to ream down with a larger bit and case the hole in order to recover the first bit. Sometimes it is possible to jar the bit loose by pounding on top of the rods.

A cave, fault, or mud seam in the rock is always more or less serious, and often involves reaming down to this point and casing through. The expense of this is considerably greater than the initial cost of the hole, and in order to avoid it a chance is often taken and drilling is continued through the soft ground for 10 to 20 feet and on into the firm rock. There is considerable danger in this, for the rods, which are usually supported by the sides of the hole, will bend of their own weight if unsupported, and, consequently, when a cave is passed through, there is a tendency for that part of the rods in the cave to bow out. On the Rondout Pressure Tunnel the drill rods snapped under this tension at a depth of 348 feet, and, owing to the play of the top of the rods left in the hole, it was impossible to tap into the end. Repeated attempts were made toward this end with the aid of an electric magnet, but it was finally necessary to abandon the bit.

Loss of water through seams or fissures often requires reaming and casing. It is absolutely essential that a sufficient supply of water be furnished to keep the bit cool and carry away cuttings, otherwise the bit will become wedged.

The wear on a bit depends very greatly on the character of the rock and its relative hardness.

Difficulties of the Shot Drill

The shot drill is more or less subject to all the difficulties of the diamond drill, and in addition has a number of troubles peculiar to itself. Its chief advantages are that it does not need expensive bits, and the possible loss in a hole is not so great; also, that a hole larger than 2½ inches to 3 inches can be drilled

more cheaply than with a diamond bit. It is much less reliable and more easily stopped, and is a much cruder machine. There is no effective regulation of pressure or of feed.

The principal difficulties with shot drills are due to the character of the bit and cutting agent. The shot are loose under the bit, and, if a seam or a crack is encountered, they roll out and leave the bit without cutting power. If the seam or crack be water bearing and of any capacity, the shot will be carried away as fast as put in; and the machine is absolutely blocked, unless the hole be cased through the seam and continued with smaller size bit, or unless the hole be reamed down to the seam to allow of larger casing.

The core barrel is usually 10 feet long and the calynx comes directly on top and is supposed to catch all the cuttings. It is difficult to gage the stream of water supplied so that it will carry cuttings into calyx without carrying shot from the under bit, and the calyx often fails to work. It is then necessary to frequently wash out hole with a powerful stream of water, or to use a sand pump in order to keep bit from blocking.

It is not possible to have any core lifting attachment on the shot drill as it would interfere with the feed of the shot. The means adopted of wedging in core barrel by washing sand between core and barrel is tedious and uncertain, and when cores are dropped they become badly ground, besides causing the delay incident to broken ground.

Reliability of Records

All boring records whether from wash, diamond drill or shot drill holes require the most intelligent interpretation based on extended experience for thorough understanding provided anything more than a rock profile is desired. An inexperienced engineer can be very easily deceived by the operator both as to character, materials encountered and difficulty of work, and the apparent results are often deceiving in themselves.

In wash boring the tendency is always to indicate coarser material than is encountered, especially when powerful pumps are used. The finer material is dissolved and carried off and a much greater portion of the larger particles remain in the sample pail. Clay or silt shows a tendency to appear as sand, and sand to appear as gravel. This is especially true when sinking is slow and the material for feet around the bottom of the hole becomes washed out.

Remedies for this are the taking of dry samples in clay, mud, etc., and covering the discharge pipe with bagging to catch as much of the finer materials as possible.

Samples are not altogether accurate as to point of taking, especially when steam pumps are used.

The percentages of core received from different holes are often used as a criterion of the relative conditions of the rocks, but there are in addition four important points to be observed which greatly affect these percentages.

1. The type of machine and its condition.
2. The skill of the runner.
3. The skill of the diamond setter.
4. The dip of the rock.

(1) An old machine whose gears are worn or loose causes the drill rods to revolve in an orbit instead of around an axis and tends to chew up core. This is also the case when a machine is set up in a shaky position or when the core barrel or drill rods are crooked or worn.

(2) Generally speaking very hard rock should be drilled with slow revolutions and heavy pressure and soft rock with quick speed and light pressure. Reversal of these conditions usually results in grinding up the core. An inexperienced runner will drop core out of the core barrel. This necessitates grinding it up unless he can let the bit down over the top again.

(3) Different kinds of rock demand different clearances and different types of setting, which has considerable to do with the amounts of core recovered.

(4) If the bedding planes of a stratafied rock lie at a pronounced angle to the vertical, the rock will core poorly. Thus a thin bedded stratafied rock lying at an angle of 45 degrees might be in an excellent position for tunneling but would show poor percentages of core. The same rock lying flat owing to its weak and thin beds would be very poor for tunneling but would give good cores.

It is important to be sure that the core barrel is straight and that the hole is started vertically. There are records of holes diverging 300 feet in a depth of 900 feet.

On the Rondout Pressure Tunnel most of the holes were drilled 20 or more feet off line. Although great care was taken in starting these holes straight, three were encountered in the tunnel. The first diverged from the vertical 3.6 feet in a depth

of 470 feet; the second 16.6 feet in 440; and the third 53.6 feet in 440.

The shot drill tends to magnify the difficulties of the ground explored as it is unable to proceed through even the smallest seam on account of loss of shot from under the bit until the seam is

The final interpretation of rock borings involves the determination of dips, strikes, and faults from the cores and the differentiation of the different strata and requires the greatest judgment and experience when the underground conditions are to be faithfully reproduced. It requires the careful consideration of trained geologists and should not be undertaken by the engineer unassisted. In the usual case, however, the advice of the geologist can be obtained only at intervals and the number and best location of holes to secure proper development is left largely to the engineer. Discussion of the process of development is beyond the scope of this article, but in the opinion of the writer the best results are obtained by locating holes so as to strike directly at critical points rather than to depend on narrowing down critical areas by a process of elimination.

The proper keeping of cores and records is the duty of the engineer and his inspectors. The rock cores should be preserved at least until the completion of the work for which the borings were undertaken and in such a manner that they can be readily identified. The following method has given satisfactory results in the preservation of over 15,000 feet of core varying in diameter from ⅞ to 1⅞ inches. Each box 8 feet long 1½ feet wide and 3 inches deep, contains a single layer. The core from a hole is laid continuously in rows from top of box to bottom, each row being separated by thin strips of boards. Elevations every ten feet are marked permanently on both core and box. Each piece of core removed for samples, test, etc., is replaced by a piece of wood of equal length. As soon as a box is filled a cover is placed on it and screwed down so that the core cannot be displaced but can be gotten at readily for inspection. On the top and end of each box the number of the hole and the elevations of core contained is painted.

An interesting and unique method of displaying the results of borings is shown on Fig. 4. After the borings on the Rondout Pressure Tunnel had been completed, a section across the Rondout Valley, about five miles long, was taken and the different strata were plotted on a board to a distorted scale. Actual cores

from the different holes were then fastened to the board in the proper relative locations. This was very useful in enabling contractors and others inspecting the proposed work hurriedly to

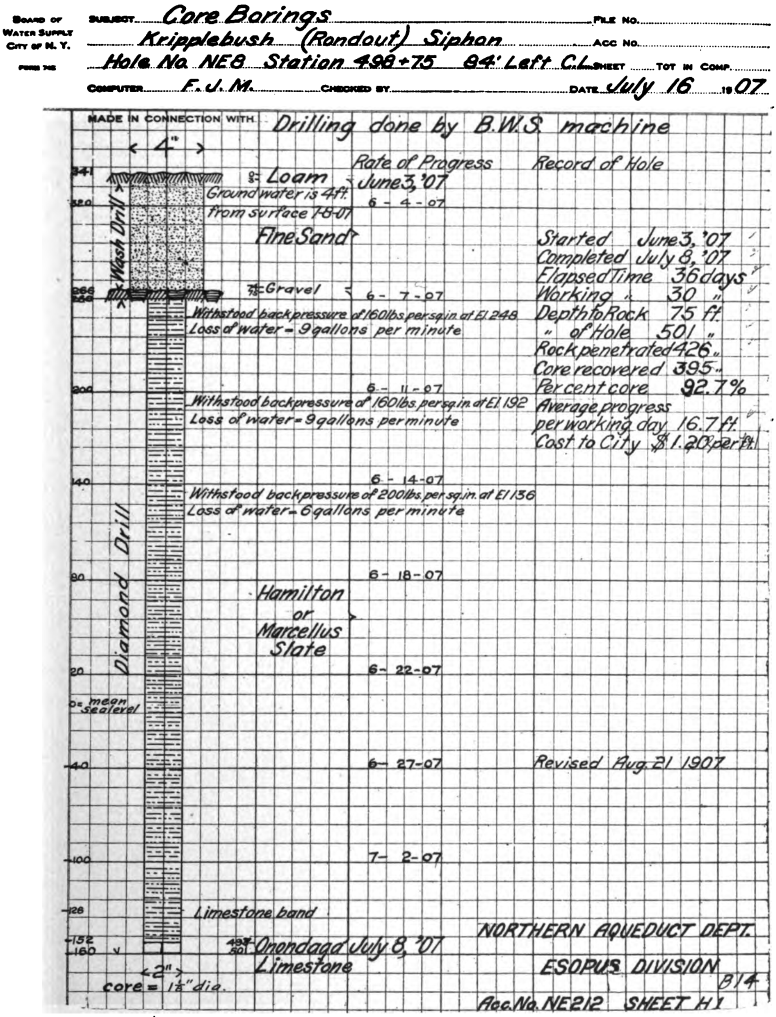


Fig. 5.

grasp quickly the relation of the different strata and their characteristics.

The records taken during the drilling should be as complete

as possible. Boring work is done " in the dark," and anything which may throw light on the underground conditions is of importance. The most minute details of the work may later on have an important bearing on the proper interpretation of the cores. A sample of a sheet prepared for each hole to summarize as far as possible graphically the most important information is shown in Fig. 5.

It is hoped that the tendency of an article of this kind to exaggerate difficulties will be discounted by the reader. *With good equipment and experience* a great majority of the holes present no special difficulties and like prosperous nations they have no history.

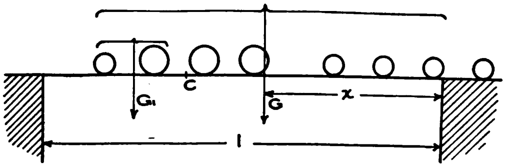


Fig. 1

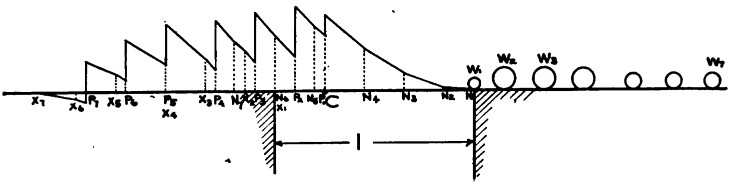


Fig. 2

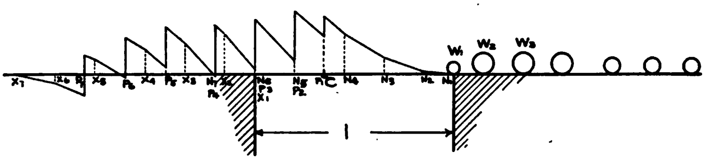


Fig. 3

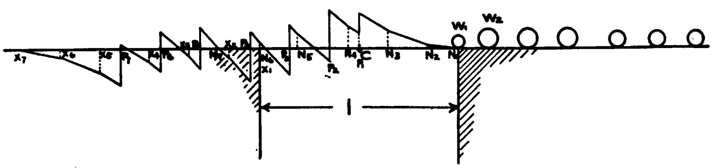


Fig. 4

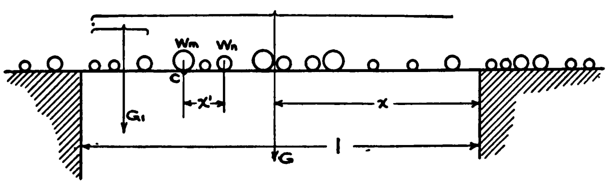


Fig. 5

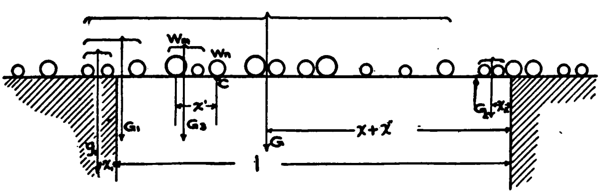


Fig. 6

A GENERAL CRITERION FOR MAXIMUM SHEAR FROM A TRAIN OF MOVING LOADS

BY LEWIS JEROME JOHNSON, '87

Professor of Civil Engineering

In studying how to place a train of loads so as to produce a maximum shear at a given section of a beam, it is customary to introduce certain arbitrary limitations for the sake of simplifying the problem. The conditions of practice usually fall within the field of these limitations and little inconvenience is caused.

Nevertheless it will be worth while to treat this problem without these limitations. Though the actual result in full will not often come into play, the process of development may shed useful light upon the nature and scope of the problem.

The problem may be specifically stated as follows:

The Problem

Given any train of vertical loads (*e. g.*, a railway train) unchanging in number, magnitude and spacing, supposed to move over a given span.

Required, the position of the train which will produce the maximum shear at a given point of the span.

Solution

It will be simplest first to solve the problem for maximum *positive* shear, and make the solution general at the close by showing what modifications are needed to make it cover maximum negative shear as well.

Fig. 1

Suppose C of Fig. 1 to be the section in question, G, the resultant of all the loads on the span, distant x from the right abutment, and G_1, the resultant of all the loads between C and the left abutment as shown.

The shear at C may by familiar principles be written

$$V = \frac{Gx}{l} - G_1 \tag{1}$$

which may be positive or negative according to the relative magnitude of the two terms of the right member. It is a function represented, for fixed values of G and G_1, by a straight line with a positive slope, and even if G or G_1 change, nothing will cause the slope of the line represented by (1) to become negative. Upon further consideration of (1), it appears that V is a function which increases with x at a rate proportional to G, and hence more rapidly as wheels enter the span and more slowly after they leave, and that V can be changed in sign only by wheels passing C, causing instantaneous reductions in V.

FIG. 2

These facts will be seen more clearly by plotting in full the V for a point from the time the first wheel of a train enters a span until the last one leaves it, as has been done for a given span and load for three different positions of C in Figs. 2–4. The wheels, marked $W_1 \ldots\ldots\ldots\ldots W_7$, with weights proportional to their diameters and spaced as shown at the right, are supposed to move over the span from right to left, and the value of V at the point C for any position of the train is set up as an ordinate at the point *then occupied by* W_1, *i.e.*, W_1 may be regarded as carrying the ordinate whose length, varying with V, defines the desired curve.

This curve changes from a fixed straight line only upon the entrance of a wheel into the span, the passage of C by a wheel, and the exit of a wheel from the span. At the foot of each ordinate in Figs. 2–4 is a letter N, P, or X respectively indicating these changes and bearing subscripts corresponding with the number of the wheel whose entering, passing, or leaving causes the change. Thus the change in the curve at the ordinate N_4 is due to the entrance, at the instant when W_1 reaches N_4, of W_4 into the span. The curve naturally continues till after the last wheel has left the span and ceases a train's length to the left of the span.

Inspection of (1) either as an abstract expression or as plotted in Figs. 2–4, at once reveals two things:

1. The discontinuity of the function precludes the possibility of applying the usual differentiation method of studying the maximum.

2. We are reduced to a cut and try method and our only hope is to make this process as brief and direct as possible.

Proceeding, we note that *the desired maximum, whether positive or negative, will never occur except when a wheel is passing C.* We should certainly get the maximum sought by successively setting all the wheels at the point, computing the corresponding values of V, and determining the maximum by comparison of the results.

We have thus established that the number of trials need in no case exceed the number of loads.

The next step is to see what can be done to minimize the labor of making these trials. Progress will be made if we can still further reduce the *number* of trials and also if we can minimize the labor of deciding between two positions for the loads after two promising positions have been selected. Consideration of the latter of these two plans will open the way to conclusions as to the first of them and it will accordingly be taken up first.

The question now is how most easily to select between two rival positions of the trains.

A position of the train is defined by stating the position of any wheel. It is merely a question then of deciding which of any two loads of the set, W_m or W_n, must be at C in order to produce the desired maximum. The only way of doing this short of actual computation of the complete numerical value in each of these cases is to see if one of them cannot be selected on *a priori* grounds. The safe way to do this is to compare general expressions for V for the two different positions. These are after all computations of the values of V in each case, but being expressed in letters the facts governing the conclusion at issue do not become lost to view as they would in the mere particular cases unavoidable in numerical work.

General expressions for V with two different loads at C will now be deduced and compared.

Let it be a question of deciding whether W_m or W_n of the set shown in Fig. 5 shall be at C, the left hand of these two loads

being called W_m. Let the two values of V, corresponding to these two positions, be called V_m and V_n. It appears at once that

$$V_m = \frac{Gx}{l} - G_1 \tag{2}$$

Moving W_n to C, as in Fig. 6, and calling x' the distance between W_m and W_n; G_3 the resultant of W_m and all wheels intervening between it and W_n; g_1 and G_2, the resultant groups of the loads leaving and entering the span respectively; x_1 and x_2 the distances of g_1 and G_2 from the left and right supports respectively, we can write

$$V_n = \frac{G(x+x')}{l} + \frac{G_2\,x_2}{l} - \frac{g_1(l+x_1)}{l} - (G_1 + G' - g_1) \tag{3}$$

Subtracting (2) from (3) we can get a $\Delta V = V_n - V_m$, the sign of which will tell which of V_m and V_n is the greater without knowing the actual value of either. This will enable us to judge the merits of a trial position without full computation. The only question is whether the step justifying such rejection is less laborious than the full computation which it obviates. This remains to be studied.

Proceeding,

$$\Delta V = V_n - V_m = \frac{Gx' + G_2x_2 - g_1x_1}{l} - G_3$$

whence it appears that for maximum positive value of V, W_n or W_m must be at C according as

$$\frac{Gx' + G_2x_2 - g_1x_1}{l} - G_3$$

is a positive or negative quantity.

Since we are concerned merely with the sign and not the magnitude of this quantity we may clear it of fractions by multiplying it by l when it will appear

$$Gx' + G_2x_2 - g_1x_1 - G_3l$$

and W_n or W_m will give the larger shear at C according as this polynomial is positive or negative. They will give the same result if the polynomial is zero. The terms involved are easy of evaluation,

frequently one or both of G_2 and g_1, vanish, and the gain over outright numerical computation is a distinct one.

The criterion sought may now be written in final form

$$\begin{matrix} W_n \\ W_m \text{ or } W_n \\ W_m \end{matrix} \left\{ \text{if } Gx' + G_2x_2 - g_1x_1 - G_3l \begin{matrix} > 0 \\ = 0 \\ < 0 \end{matrix} \right.$$

To determine the maximum positive shear at any point the leading wheel is taken as W_m and the other wheels successively in order as W_n until the criterion has a positive value. The wheel then taken as W_n is noted, taken as a W_m and the work continued until all wheels have been tried. The final W_m is evidently the wheel sought.

The maximum *negative* shear at any point C can also be determined by the preceding methods. It is only necessary to observe that it is identical in amount with the maximum *positive* shear at the point C' symmetrical with C with regard to the centre of the span. The wheel at C' giving the maximum positive shear at that point is the same wheel which will *with the wheels reversed* give the maximum negative shear at C.

Of course, comparison of actual numerical values of V will be resorted to whenever it saves labor to do so.

In practice and with a little experience it will be found unnecessary to make many such trials because the promising wheels may often be picked out almost at a glance with the aid of the general principles already established.

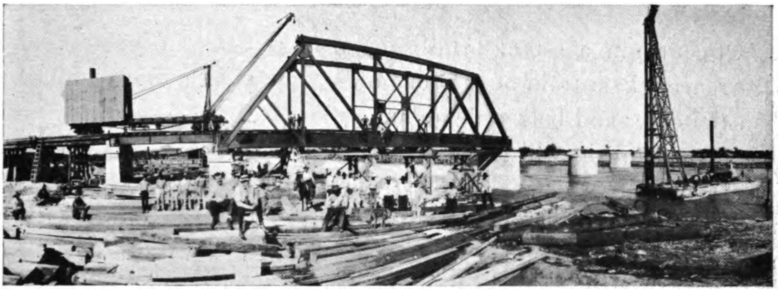
Furthermore, when G_2 and g_1 vanish and G_3 is simply one wheel which may be designated as P_m, there results the familiar form of the criterion

$$\frac{Gx'}{l} - P_m$$

The use of a straight edge of a piece of paper having the loads set off along it to scale to be moved at will on the span like a miniature train will often be of great assistance in this as in other problems involving moving loads.

Of course in a set of loads subject to reversal in its order of occurrence, like a train of cars, one order may yield a greater result than the other and both orders must be studied.

In general it will be observed that for a maximum shear (whether positive or negative) at a point C, there should be as much load as possible between C and the further abutment, the heavy part of this load as near C as possible, and as little as possible between C and the nearer abutment.



Piers completed, view being taken on American Bank. Pier No. 2 is the nearest pier in the water. Notice bank protection work on the Mexican bank.

FOUNDATIONS IN THE RIO GRANDE

BY GEORGE A. MCKAY, '08

During the past twelve months the writer has been stationed at Brownsville, Tex., where a new bridge across the Rio Grande has been in the process of construction. This bridge is about twenty-two miles from where the river empties into the Gulf of Mexico, and is several hundred miles nearer the mouth than any bridge previously erected. It is a combination railroad and highway bridge, and has been built jointly by the St. Louis, Brownsville, and Mexico R.R., which is a part of the great Frisco System, and by the Mexican National Lines. When open for traffic this bridge will afford the shortest route between New Orleans and Mexico City, and will undoubtedly get most of the through freight and passenger service between these points. All this traffic has been forced, until now, to cross the river at Laredo, or even further up. This new gateway will play an important part also in the development of a wonderfully fertile agricultural section, which has only recently been appreciated and opened up.

The Rio Grande at the bridge site is comparatively narrow,— not over 420 feet from bank to bank. This stream is similar to many other rivers in the Southern states. It flows in a meandering course through very level country, and its banks present a marked contrast to those common among rivers in the Northern states. In New England, for example, nearly all rivers are restrained within banks which are relatively permanent,

being composed of either rock itself, or soils of glacial origin which readily withstand the cutting action of the current. The banks of the Rio Grande near Brownsville, on the contrary, are composed entirely of alluvial soil, all of which has been deposited during former overflows of the river. As has been mentioned, the course of the river is extremely tortuous; and the way of computing the distance by river, between two river towns, is to multiply the actual distance by four. The river reaches its lowest stage each year during the months of March and April. Each year in May, when the snows are melting in the mountains of Colorado and Mexico, the river begins to rise, and flows bank-full for weeks at a time. During these periods of high water the current is very strong, and is able to cut into its easily eroded banks, and to materially alter its course. The whole region, within ten miles of the river on either side, contains numerous crescent shaped lakes, which show where the bed of the river has been. At such times the river carries an immense amount of drift, composed of branches, and tree trunks which have been undermined along its banks.

With these preliminary considerations in mind, the design of the foundations will be discussed. A set of borings, made by the railroad company in 1906, was used as the basis. The borings showed that the bed of the river was composed of a shifting layer of quicksand, nearly level on top, but varying in depth, from 22 feet on the American bank to 12 feet in the center of the stream, and only 8 feet deep near the Mexican bank. This layer of quicksand overlaid a strata of excellent yellow clay, free from sand, impervious to water, and of great depth. Pneumatic caissons were considered, but the high cost of this method was deemed prohibitive. The type adopted was that of concrete piers, with spread footings, resting on wooden piling driven well into the clay. The footing courses were designed sufficiently large to give a maximum load of 2 tons per square foot. Disregarding the bearing power of the soil, enough piling was used so that the greatest load on any pile would be 15 tons. As the Rio Grande is considered a navigable stream by the War Department, it was necessary to have a draw span in the bridge. This feature determined largely the nature and location of the river piers. It called for a massive circular pier in mid stream, to support the draw-span and its attendant mechanism. It made two other river piers desirable, one to take

each end of the draw-span and to support the end of the span from each bank. The foundations of the bridge proper thus consist of five piers, one on each bank and three in the river. These piers are numbered consecutively: No. 1 being the shore pier on the American bank, and No. 5 on the Mexican bank. The spacing of these piers is as follows: 126 feet from No. 1 to 2, also from 4 to 5, and 113 feet 7 inches from No. 2 to 3, and from 3 to 4. In addition to the main part of the bridge, a short girder span, 32 feet long, was added at each end to span the highways along the banks. The American pier, called Pier O, has a spread footing and pile foundation; and is designed to carry one end of the short girder, and also act as terminal of the trestle approach to the bridge on the American side. Elevation of rail here is 16 feet above the level of the bank. On the Mexican side, however, the short girder span rests on an abutment called Pier No. 6. This abutment is carried down to clay, and was also designed to have foundation piles. The abutment has wing walls, and terminates the 16-foot fill, which is used as approach on this end.

The contract for the foundations was let to The Foundation Company of New York, and the contractor started work in May, 1909. The first step was the erection of temporary buildings, for cement storage, another for tool house, others for office, and for use of the men. Two sets of pile driver leads were also framed: one for the land driving, 60 feet high; the other for the river driving, 72 feet high. A barge was also built on the bank and launched. This barge, 30 x 60, was built to carry the 72-foot pile leads, a 4-drum hoisting engine, and the necessary boiler and pump. The necessary piling and timber for the bridge job could not be obtained near Brownsville: in fact, headquarters for all supplies were at Houston, over 350 miles distant. The piling and timber had to come 200 miles further; and as the movement of freight in Texas is extremely slow, many exasperating delays were experienced, on account of shortage of material.

The first work on the piers was at No. 1. This was excavated by hand to about 6 feet below the ground level; then two sets of 12 x 12 waling, the same size as that of the bottom footing course, were framed, and located one above the other, and about 3 feet apart. Then 3-inch tongue and groove sheeting, 16 feet long, was driven. This was driven by using a 2,800-pound

drop hammer, working in a set of swinging leads suspended from the end of the boom of a stiff-leg derrick. Excavation was then carried to the desired level, or Elevation 28.5 of a datum used by the railroad, and called sea-level. Little water was encountered, and this was easily handled by a 2-inch steam syphon. The soil at Elevation 28.5 is nothing but quicksand. This pier rests on sixty-six 45-foot piles, which have an average penetration in clay of 18 feet. In driving, the pile driver rested on stringers which spanned the excavation. The hammer used was the 2,800-pound hammer, but the driving through the 20 feet of quicksand proved to be hard slow driving. The quicksand sucked in around the pile, and acted much like a rubber cushion. The hammer would rebound from the head of the pile, and the force of the blow was partially lost. To overcome this, resort was made to "jetting." A 2-inch iron pipe, with a nozzle at the end was suspended in front of the pile leads. In driving by this method, the pile was swung into position in the leads, and the point located and set on the ground. A high pressure pump connected with the jet was then started, furnishing a pressure of 80 pounds per square inch at the nozzle. This jet was then lowered alongside of the pile. The water, at this pressure, quickly loosened up the dirt and quicksand as the jet was lowered, and the weight of the hammer on the top of the pile caused it to sink with scarcely a blow. The jet was useful until it reached the clay. From there, the hammer did the rest of the work, while the jet kept the quicksand from closing in around the pile.

As soon as the piles were driven, they were sawed off so as to stick up into the concrete one foot. Concrete was then deposited to a depth of 3 feet. The mixture specified for the piers was "one volume of Portland cement to six volumes of the total mixed aggregate of sand, gravel, or crushed stone." The sand used on this work had to be transported about 400 miles. The gravel was found 75 miles away. This was found in a very peculiar deposit: The pebbles were all rounded and waterworn, and were cemented firmly together by a chalk-like calcareous matrix. These deposits are extensive; are about 15 feet thick; have to be loosened up by drilling and powder, and it was necessary for the contractor to install a crushing and screening plant to separate the gravel from its objectionable matrix.

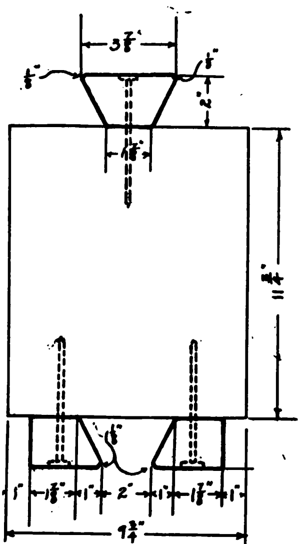
The footing courses only in Pier 1 had been deposited when the river rose, overflowed the bank on the American side, flooded the work here; and made it necessary to transfer operations to Pier No. 5 on the Mexican bank, which is about a foot higher and did not overflow. The excavation here was accomplished in the same manner as before. The soil, however, was different; and although the bottom of the lowest footing course was the same as in No. 1; *i.e.*, Elevation 28.5, in No. 5, it was a stiff clay. In driving these piles, one minor detail, different from No. 1, is worthy of mention. Shorter piles were used, — 36-foot lengths, — and it was necessary to drive them down to the cut-off. As the pile driver was standing on cross timbers, about 12 feet above the bottom of the excavation, it was impossible to drive them to cut-off without the hammer going below the leads An extension to the leads, therefore, was constructed about 12 feet in length. This was hung by a set of heavy strap-hinges to the bottom of the driver leads, and when in position would allow the hammer to follow the pile to the bottom of the excavation. When moving the driver, and it was necessary to clear the supporting cross timbers, this extension would fold up neatly in front of the regular leads out of the way. As there was no quicksand, a jet was not necessary here, and instead of the drop hammer, a No. 1 Warrington steam hammer was used; which, with its sharp short blows, gave better results in the stiff clay.

In placing the concrete in Pier No. 5, one circumstance arose, which would not occur on any other job except one of international character. There is a duty on all cement which passes from the United States into Mexico, which amounts to about 70 cents per barrel. It had been the original plan to mix all concrete in the mixing plant, which had been installed on the American bank with this end in view; and to take the mixed concrete to its destination on small cars, running on an industrial track, for which a temporary tramway was to be erected across the river. But it was found that if this was done, duty would have to be paid on the whole mass, just as though it were all cement. But since sand by itself, and gravel by itself, may be crossed free, it was decided to transport the ingredients by barge across the river, and mix them there. Mixing by hand was tried, but given up after one day's trial; and the mixing plant was transported, and set up on Mexican soil.

Little excavation was necessary for the abutment; *i.e.*, Pier

No. 6, and this pier, with No. 5 was carried up at the same time; the carpenters working on the forms in one, while the laborers were placing concrete in the other, and vice versa. The work on the concrete forms was all very simple. Locations, center-lines, and elevations were all given by the resident engineer; and as the form work presented no unusual features, it will not be described. It may be well to mention, that in Pier 6 the resident engineer made a departure from the plans. Excavation for this was carried down until an excellent stiff clay was encountered, of sufficient bearing power to easily sustain twice the greatest load; the foundation piles were, therefore, omitted.

The piers in the river were constructed in open cofferdams. The original plan was: First — to drive the foundation piles, following these down to their cut-off by means of a "follower," which will be described later; second — to drive a cofferdam around each pier site, of the same size as the bottom footing course; third — to excavate the material with some form of dredge down to the elevation required; fourth — to deposit the first footing course through water, by the "tremie" method, and allow this concrete to set up. It was then thought that the dams could be pumped out and finished in the open. The sheet piles, of which the cofferdams, as planned, were built, were of 10 x 12 yellow pine, all heart stock. These were each 36 feet long, and were converted into a form of interlocking wooden sheeting by oak splines, of a shape as shown by the accompanying cross-section. These oak splines were astened to the 10 x 12's by lag screws, ¼ of an inch by 5 inches, spaced about 3 feet apart, and a 60 d spike was driven between each two lag screws.



FIG—1
CROSS SECTION OF
SHEET PILING

The original plan, as stated above, was followed on two of the river piers; *i.e.*, Nos. 3 and 4. The foundation piles were driven first, and only two features of this work deserve notice. These two concern — first, the location of the piles, and second,

the following of these piles to the required cut-off. In the location, or "spotting" of the piles, two lines were necessary, one parallel to the center line of the bridge, and the other at right angles to it. For lining in the piles parallel to the centerline, a transit was used, set up on the bank over hubs spaced as per plans. To get the right-angled spacing, a location frame was established in the river about 100 feet above the pier site. This frame was built on four temporary piles, so spaced as to form a square the size of the pier, or slightly larger. The piles were capped with timbers parallel to the bridge centerline. A point was then located on each of these timbers by direct measurement with a 300-foot tape. These points were directly up stream from the center of the pier where the piles were to be driven; and boat spikes, 6 inches long, were driven at the points and painted white. It was then an easy matter for a man on the barge to get on his centerline by moving his barge until these two spikes appeared in line to him, sighting between the driver leads. Other sets of spikes were also driven at equal distances from the first two, and spaced as the plans called for. The locating was thus done by only one man with an instrument. Each pile, when driven, was marked off on a chart.

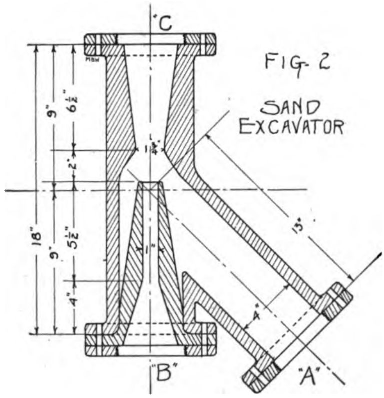
The plans called for driving the piles until their heads were at Elevation 15. This meant about 18 feet below the surface of the water, and about 6 to 10 feet below the bed of the river. This was accomplished in the following manner: The piles were first driven by use of the jet and the steam hammer, until the head of the pile was almost to the water's surface and the hammer was in danger of coming out of the leads. The hammer was then lifted and the "follower" was placed on the head of the pile. This follower was a hollow steel tube, 14 inches in diameter and 20 feet long. It had a cup-shaped lower end to fit over the pile. The rest of the tube was filled with a tough wooden plug, which was shaped so as to snugly fit the pipe. This plug extended to within a foot of the top. The last foot was left so that another short plug could be inserted to take the direct blows of the hammer, and could be replaced when badly broomed. For these plugs black gum, an extremely tough wood, was used with fair success. With this follower over the head of the pile the hammer was started again, and the driving continued until the required elevation was reached. The pile line was then fastened to the follower, and drew it up off of the

pile. It was often necessary to use the jet to loosen up the sand around the pipe before it could be pulled. In the case of Pier 4, clay was encountered at Elevation 20.5, or about 5 feet higher than shown by the borings. This meant that in driving to Elevation 15, the follower must go 5½ feet into the clay; and, as can easily be imagined, considerable difficulty was experienced in withdrawing the follower. The clay was so stiff, that the pull was against a vacuum as well as against the side friction; and the barge had to be used as a battering ram, being pulled from side to side, batting the follower with alternate sides of the leads, all the time keeping a strain on the pulling line.

The original plan for Pier 2 was to have the bottom footing at Elevation 12, which would leave nearly 7 feet of quicksand between the footing and the clay. Some uneasiness was felt by the railroad officials about this design, and the plan was finally changed to carry the pier down to clay. It was thought best to excavate the pier first, before the foundation piles were driven, so the first step here was to drive the cofferdam. This was done by using a stiff-leg derrick, which was located in the river on a 4-pile tower, and with 3 piles under each stiff-leg: The engine was on the bank. A set of waling was then located, and was bolted to temporary piles, driven within the pier area. The sheet piling, to which the oak splines had been previously fastened on the shore, were then set in place. The first pile had to be set with considerable care, to get it plum both ways, and this pile was then hit a few blows with a drop-hammer, working in a set of swinging leads suspended from the end of the derrick boom. The rest of the sheet piles were then hoisted, one by one, by the derrick, and each tongue entered into the groove of the preceding pile. This whole dam was thus put in place and interlocked all the way around, before any attempt was made to drive the piles. In driving, the drop-hammer was used, working in the swinging leads already mentioned; and with this rig the piles were driven until their heads were at Elevation 35, which gave their points a penetration of 6 feet in the clay. Submerged logs and other sunken drift were encountered, and steel shoes were used on part of the piles. In spite of precautions and care in driving, some of the splines tore loose; and when a pump was installed, it was found that the dam could not be pumped.

So plans were made to dredge out the quicksand without

pumping. First an admirable little device was tried, a "sand excavator," invented by Waddell and Hedricks of Kansas City. A cross-section of this is shown herewith. It is suspended from a derrick, and lowered into the water until its suction "A" touches the sand. A stream of water, under a pressure of 80 pounds, enters at "B." The force of this water, combined with the shape of the passage creates a suction at "A," and sand is sucked up with the water and flows out through the discharge "C." This device worked well at first, lifting large quantities of sand; but at a little depth below the bottom so many sunken twigs and branches were encountered, that its efficiency was greatly reduced. Attempts were made to collect and remove these, using a diver; but this proved impracticable, and resort was made to a clam shell bucket. This worked much better, although an orange-peel bucket would have been just the thing. The lips of the clam-shell had the tendency to scrape over the bottom without picking up the hard packed sand; still, progress was fairly rapid. When the outside pressure on the dam began to be a factor, a second set of waling was framed, floated into place, and sunk by weighting with the drop-hammer. This set of waling was sunk as fast as the inside level of the sand was lowered, but this set was probably of more value as a precaution against collapse than as a source of strength. A powerful water jet was used to float the quicksand around the edges of the cofferdam in towards the center where the dredge could reach it. The same jet was also used outside of the dam, to float away some of the quicksand which was against the sheet piles, and in this way to reduce the outside pressure on the dam.



Clay was reached at Elevation 5; but the clam-shell bucket was kept working until it was bringing up good clay with each load, and the resident engineer was satisfied that a good bottom had been reached. The foundation piling were then driven, using the land driver working on a temporary pile platform.

Piles were followed to Elevation 15, as originally planned; there were a few exceptions which could not be driven to that depth, and these had to be sawed off, using a cross-cut saw in a sawing frame made of 1½-inch pipe, at a depth of 13 feet below the water surface. While these piles were being sawed off, it was discovered that in driving the last row of foundation piles, the inside pressure due to the crowding of the clay had caused the cofferdam to open in three or four places. A set of soundings were then made, and it was learned that mud and sand had

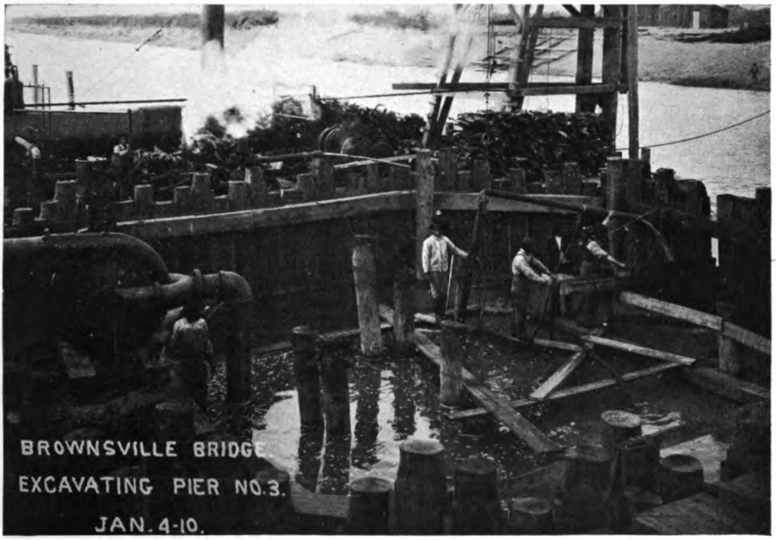


PLATE 2.

Sand Excavator at work. Excavator is sixteen feet below water surface. Note interlocking cofferdam.

started to run in through these openings and had spread over the clay to a depth of 3 feet. This, no doubt, was due partly to a 4-foot rise in the river. The openings were at once closed up by driving 3-inch planks over the openings on the outside, and by further ramming oakum, fine gravel, and horse manure between the splines and the planks. It was impossible to use the clam-shell bucket again on account of the pile heads. The sand excavator was again put in. This brought up some sand and mud, mixed; but progress was slow, and soundings taken after four

days and nights of continuous operation, showed that only 18 inches had been gained. The foot or more of residue still over the clay, however, was soft, and could be easily penetrated by the sounding pole, and it is very likely that almost all the quicksand had been removed by the excavator, leaving only the mud on the bottom. Taking this stand, the resident engineer decided to start concreting, maintaining that the concrete, with its much greater weight, would displace this soft mud, sink to the clay, and lift the mud as the elevation of the concrete rose.

PLATE 3.

Depositing water under concrete, by use of Tremie.

The concrete was placed through water by the use of a tremie. For this, a 20-inch diameter sheet-iron pipe, with a hopper on its top, was used. If care is exercised with the use of a tremie, concrete of a very good quality can be deposited in an open dam. It is also easy to operate. The pipe was lowered into the water until its lower end rested on the clay. Concrete, dumped by the derrick onto a working platform, was shovelled into the pipe until it was full, and all of the water had been expelled over the top. The derrick line was then fastened to a chain sling at the top of the tremie, and it was lifted very slowly

a few inches off the bottom. The weight of the concrete column would then cause the concrete to spread out slowly at the bottom. The pipe would then be lowered, and again shovelled full of concrete. In lifting the tremie, care was taken to drop the tube when the level of the concrete had only fallen about 6 feet. This kept the water from coming in at the bottom. Occasionally the charge would be lost, but not often. The only poor concrete was that which was dropped through the water in "charging" the pipe.

PLATE 4.

Frame for secondary cofferdam at Pier No. 2. This was planked and caulked, then lowered into position by rope and wooden blocks.

By this method concrete was placed until a layer, 15 feet thick, reaching from Elevation 5 to Elevation 20, had been deposited. When this concrete had hardened, another attempt was made to pump the dam, but it was unsuccessful. It was then decided to build a secondary dam in position inside of the original cofferdam; to caulk this thoroughly with oakum, and then to lower it into place. This was done, using 3-inch plank and 6 x 6 studs, and this was sunk and weighted down until its bottom rested on the concrete already in place. About 2 feet

of concrete was then deposited by use of the tremie; this was considered enough to seal off the bottom, — it brought the concrete up to Elevation 22.2 When this concrete had hardened, a 4-inch Emerson pump was hung in place, and the dam quickly pumped dry. Nearly a foot of mud and slush was found on top of the concrete, thus bearing out the theory of the engineer that the concrete would lift the soft mud which had not been removed before concreting began. There were also a few inches of poor concrete on top; but when this was removed, the main body of the footing was found to be of excellent quality. The forms for the shaft were then built up in the open and the pier completed without further difficulty.

At Pier 3, where the foundation piling had been driven first, it was decided to drive the sheet piles with the steam hammer; and to drive them one at a time, carrying each to its final elevation before another one was set up. This was done by framing an overhanging, yet rigid, set of leads, which projected out about 3 feet in front of the regular leads. This allowed the barge to be pulled up closer to the dam, and gave a straight drive. Considerable care was used in driving this dam. Each sheet pile was sharpened so as to crowd it against its neighbor already in place; and the dam when completed looked much better than the dam at Pier 2, which had been all set up together before it was driven. A trial, however, showed that the dam could not be pumped.

In excavating this pier, the sand excavators were used altogether. There was no drift to interfere here, and for the most part the excavators worked excellently, though rather slowly. Clay at this excavation was found at Elevation 5, the same as at No. 2. This was 10 feet lower than shown by the original borings; and, inasmuch as No. 2 had been carried to the clay, it was decided to do the same at this pier. As the depth of water increased in the dam, the amount of sand lifted became smaller. Two excavators were kept running night and day, until clay was reached. Progress was so slow that it seemed probable that the quicksand was running in between the piles and splines; but at length, by working both excavators on one side of the dam, clay was reached on that side, and the engineer decided to place concrete there, using the tremie. About 50 yards were placed during one afternoon; it was further decided to continue with the sand excavators all that night, so as

Plate 5.

Concrete forms. View shows outer cofferdam, also secondary cofferdam in place, and forms rising inside.

to have another pocket free from sand. In the morning this was concreted. This plan was continued, placing some concrete each day, and running the excavators the rest of the day and all night, until nearly all of the sand had been pumped out, and concrete deposited over the whole bottom.

Some engineers would question the practice followed at this bottom. It is certain, however, that most of the quicksand had been removed; not over 6 inches remained, at most. It is also certain that all of the sand was removed from some pockets, and that concrete was placed in these before more sand had run into them. Even if some little sand was mixed in with the first foot of concrete, it formed, at the worst, an excellent riprap, which was all that was really necessary among the piles. And when it is considered that Pier 2 was, in the first place, thought to be of safe design with 7 feet of quicksand between its footing and the clay, Pier 3 seems safe beyond a question.

It was hoped that, with the great care with which the sheet piling had been driven at No. 3, the dam could be pumped when concrete had been carried, by the tremie method, up to Elevation 17. But a big 12-inch centrifugal pump could only lower the water 18 inches, and resort had to be made to a secondary cofferdam, built up and sunk the same as the one mentioned as used at Pier 2. This dam was equally effective, and when sealed off at the bottom, was readily pumped. Pier 3, being the pier for the draw span, was circular in shape; the details of the form construction, however, presented no particular difficulties, and this was put in place much like the circular ends on Pier 2, as was seen in Plate 5.

The main item of interest at Pier 4 was the way in which the original cofferdam was treated, so that the excavation could be done in the open and all of the concrete placed in the air. When work was started here the river was very low, and the main channel was between Piers 2 and 3. The waste dirt from Pier 5 was dumped around the cofferdam, until it made a bank whose top was several feet above water. This dirt was rammed down hard, next to the sheeting, and the dam was rendered so tight in this way that all the water was kept out easily by a small steam syphon. Excavation was done in the open, and any leaks that developed were stopped with oakum and burlap sacks. Clay here was found, strange to say, at Elevation 20.5, which was 15 feet higher than the strata in No. 3. The exca-

vation was carried down to Elevation 12.2, and the footing course was placed at that elevation on a good stiff yellow clay. It was feared that possibly this clay might be only a thin layer overlying one of quicksand, but a 1¼-inch pipe was driven down, and a core taken out of it, by using a 1-inch augur, to ascertain if this was the case. This showed, however, a continuous layer to Elevation minus 9, so no more fears were felt for this pier on that score.

In mixing and placing the concrete for the river piers, a temporary tramway played an important part. This was built from the American bank out as far as Pier 4, the last river pier. On this tramway a double line of 24-inch industrial track was laid down. Switches were so placed that three cars carrying concrete buckets could be in use at one time, — one going away from the mixer loaded; one returning empty, and one being filled at the mixer. This tramway was also very useful, when moving pumps and other machinery. It was convenient, too, as a support for steam and water lines, and for carrying fuel to the hoisting engine at Pier 3.

With the piers completed, it was the original plan to follow the sheet piling down until the heads were below the level of the lowest water. This was tried at Pier 2, using the steam-hammer. But this hard driving caused very noticeable vibrations in the pier itself, — enough to even dislodge flakes where the concrete had been patched up a little on the corners, and after putting down fifteen sheet piles, driving was discontinued for fear that the pier might be injured. The tops of the piles, finally, were sawed off, level with the water surface at a time when the water was very low; and the rest of these sheet piles, which will be entirely under water for the greater part of the year, left in place around the piers.

As a final precaution against scouring of the clay around the river piers in time of high water, a woven mattress of willow brush was sunk around each of these piers, and weighted down heavily with rip-rap. This mattress was 20 feet wide, and extended around the three sides of each pier where the water is most apt to attack the bottom. For rip-rap, burlap sacks filled with concrete, were used, as no rock was available.

The work described above was done under the supervision of Arvid Franke, resident engineer for the St. Louis, Brownsville, and Mexico R.R. The work was done by The Foundation Company of New York, with W. B. Taylor as superintendent of construction.

TESTING STEAM TURBINES WITH A WATER BRAKE

WINSLOW H. HERSCHEL, '96

When turbines are built for use with a generator, the most natural and simplest way of finding the power would seem to be from the output of the generator; but there are several objections to this method. The generator, and more especially the volt and ampere or watt meters are expensive pieces of apparatus, and liable to be injured during the tests. Besides, these meters need careful calibration and handling in order to give accurate results.

In order to avoid these difficulties it is quite usual to employ a water brake, which gives results with all the accuracy of any other Prony brake, is comparatively simple to build and operate, and is a great deal cheaper than a generator in case one has to be built especially for testing purposes.

A water brake is primarily a smooth disc, such as a blank saw blade, rotating in water contained in a casing to which a lever arm is attached. The outer end of the lever arm may rest on a platform scales, and the supply of water should be regulated both on entering and leaving the casing. The friction of the disc on the water, and of the water on the casing, tends to cause the casing to rotate, and thus a pressure is brought upon the scales, which is a measure of the power developed. For speeds less than, say, 500 r.p.m. this form of water brake would have to be made impracticably large, and some other type of dynamometer would be preferable.

The author was called upon to determine, without a generator, the power of a 500 K.W. turbine of his own design, running at 3,600 r.p.m.; and in this case the best method was clearly to employ a water brake of the type described. In the course of the tests the question came up as to the proper method of taking readings of speed and torque, and it is the object of this paper to consider this question.

The correct measure of the excellence of a turbine is not the water rate, or economy, taken by itself; but the per cent of available energy converted into useful work, which may be called simply "efficiency" without qualifying adjective. If h_1 is the

total heat of the steam at admission, in B.t.u. per lb., and h_2. the total heat at exhaust, then, calling W the water rate in lbs. per brake horse power per hour, the efficiency will be $\frac{2547}{W\ (h_1-h_2)}$. If r is the horizontal distance from the center of the water brake shaft to the point where the lever arm rests on the scales, T is the torque or pressure on the scales in lbs., and n is the number of revolutions per minute, then H.P. $=\frac{T 2\pi r n}{33000}$ But since $W=\frac{B}{H.P.}\cdot\frac{60}{t}$ where B is the total consumption of the turbine during a test of t minutes duration, we get finally:

$$\text{Efficiency} = .00809\ r.\ \frac{t}{B}\cdot\frac{n\ T}{(h_1-h_2)}$$

Since r is a constant, the first factor of the equation requires no further consideration.

Every experimenter is painfully aware of the practical impossibility of maintaining perfectly constant conditions throughout a test. It is therefore usual, in finding the efficiency of almost any form of prime mover, to take readings at regular intervals and use average values in the computations. All averaging could be avoided, however, if it were possible to determine all quantities by instantaneous, simultaneous readings. Thus in testing a turbine; h_1 would be determined from readings of a pressure gauge, and thermometers; h_2 from readings of a mercury column or vacuum gauge. T would be read on the scales, and n on the tachometer. All these readings might be made simultaneously. Now $\frac{B}{t}$ is a rate of flow in lbs. per minute, and if this could be obtained from readings of a Ventrui meter placed in the boiler feed pipe, then all quantities necessary for determining the turbine efficiency could be read instantaneously. In the present case the condensed steam was weighed in a barrel, so that two readings on a watch were needed to obtain t, and two readings of the scales to obtain B. Thus average values of h_1, h_2, n, and T must be used.

It is evident that readings for h_1 and h_2 must be simultaneous, and that speed and torque must be read at the same instant. The question to be decided is whether readings for steam conditions must be made at the same moment as readings for horse power. There will be unavoidable variations in boiler

pressure, and it is safe to assume that readings of steam conditions at regular intervals of time will give the best possible average values of h_1 and h_2. But it does not necessarily follow from this that it is preferable to take readings of torque and speed at regular intervals.

In a turbine, for given steam conditions, there is a certain speed at which the maximum power will be obtained, and it is the object of the designer to so construct the turbine that this speed shall as nearly as possible coincide with that at which the governor will hold the turbine. What a customer wants to know is the power of the turbine under operating conditions at his own plant, but this depends upon the speed variations which the governor would permit when subjected to these particular conditions. Under these circumstances complete and exact information could only be given by a diagram showing the variation of power with speed at various loads; but these variations are so slight, within the limits of speed permitted by the governor, that it is sufficient to run all tests at normal speed, that is, at the speed at which an ideal governor would keep the turbine under any change of load.

In case of tests where the speed of the turbine is regulated by the load on the water brake, which is the most convenient method in order that tests may be made at abnormal as well as normal speeds, it is impossible to keep the speed absolutely steady. Ordinarily, with the most efficient speed at or near the normal speed of 3,600 r.p.m., the man at the brake would keep the speed somewhat too low, so as to give him more time to check it in case it should tend to rise; and, if readings were taken at regular intervals, only try to bring the turbine up to full speed just before a reading was to be taken. Or if the turbine happened to be so designed that the maximum power could be obtained at 3,900 r.p.m., while the safety stop was set at 4,000, it would be merely a question of the nerve and ability of the man at the brake how much power was obtained from the turbine. Much of the effect of the personality of the water brake operator may be eliminated by taking readings only when the scales and tachometer are steady and the speed is normal, which necessitates taking them at irregular intervals of time.

The strongest reason against this seems to be that it is contrary to what a customer would expect, and he might, therefore, regard with suspicion any such method of procedure. The

author has found from his own tests that, with careful regulation of the speed, it made no appreciable difference in the result whether readings were taken at regular or irregular intervals. It might, therefore, be preferable, in order to avoid discussion, to take readings at regular intervals; although this requires the services of an additional man. One man can regulate the speed by the water brake and take readings of torque at irregular intervals whenever conditions are steady, the speed is normal and he gets a chance; it takes two to regulate the speed and take readings of speed and torque at regular intervals.

The greatest objection, from a theoretical point of view, to taking readings at regular intervals, is that it involves taking them during changes of speed. During an increase of speed the power of the turbine would consist of two parts: That shown by the brake, and that expended in accelerating the turbine and water-brake rotor. The power, as calculated from readings of torque and speed, would, therefore, be too small. If, on the other hand, the readings happened to be taken while the speed was falling, the result would be too high. It would, of course, be possible, with a little care, to have the average speed substantially equal to the normal speed, and to practically eliminate the error due to force of acceleration by taking as many readings on a falling as on a rising speed; but it seems needless to go to such trouble, if it can be shown that to take readings at irregular intervals of time is an equally correct method.

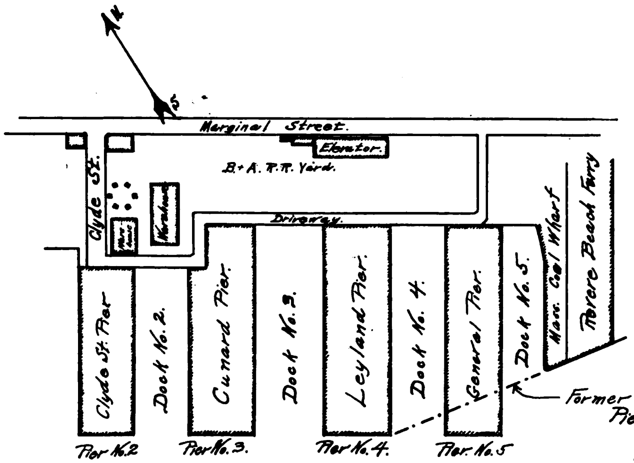
Apparently the reason why this method appears wrong to any one, not especially familiar with steam turbines, is that they assume that the consumption will vary with the speed. This is true of a steam engine and of a hydraulic turbine; and consequently appears so obvious in the case of a steam turbine, that they do not realize they have made any assumption at all, much less, an assumption contrary to fact. Yet it has been shown, alike by theory and by tests, that the weight of steam that will pass through a turbine is independent of the speed of revolution.

THE EAST BOSTON DOCKS

BOSTON & ALBANY RAILROAD IMPROVEMENTS IN EAST BOSTON.

BY HOWARD K. ALDEN, '06

On July 8, 1908, occurred the great fire on the East Boston water front, which called for immediate decision by the Boston & Albany Railroad as to its course in East Boston. The long considered improvements in docks and piers became a necessity, unless the company would abandon its facilities for delivering freight directly to the trans-Atlantic transportation companies. The decision was not slow in coming, for scarcely had the embers of the fire cooled before plans were brought to completion for the newest and largest piers in this country.



PLAN of the BOSTON & ALBANY WATERFRONT EAST BOSTON.

The Boston & Albany properties in East Boston comprised five large piers named from east to west: The Clyde Street Pier, now known as Pier No. 2; the Cunard Pier, the General Pier, the Leyland Pier, and the Massachusetts Wharf and Coal Company Pier. These made up the water front, and were backed

by the company's terminal railroad yard. The first and last named were not burned.

The structures which burned, though scarcely ten years old, were far below the present standard. They were mainly wooden buildings of the slow burning kind, although little of this latter characteristic was noticeable during the fierce gale in which they were consumed.

The Cunard Pier, in which the fire started, stood next to that at the foot of Clyde Street, its sister pier. From the Cunard Pier the fire spread to the General Pier, combined with a large wooden grain gallery of 1,000,000 bushels capacity, though never allowed to store half that quantity; wiped out the engine house and power plant in the rear, and jumped to the Leyland Pier, the farthest east that the fire reached. Only a favorable change of wind saved the coal wharf adjacent to the Leyland Pier, the Narrow Gauge Ferry slips, and the Simpson Dry Docks just beyond. Besides the value of the piers, which were well insured, the fire loss of merchandise in the Leyland Pier alone amounted to $500,000.

The first work of reconstruction undertaken was the building of a small transfer grain elevator to take care of the grain business, until a permanent structure could be designed and built. This elevator handles only outward grain from cars to ships lying at the Clyde Street Pier or to lighters in the dock, and represents no storage capacity whatever. This temporary elevator was built by the Witherspoon Englar Company of Chicago, grain elevator engineers and designers. It has paid for itself several times over in toll upon the grain transferred, besides retaining the business which would have been given, at least temporarily and perhaps permanently, to other terminal companies.

The second work of reconstruction was the rebuilding of the Cunard Pier on the site of the old one. The new shed is 772.5 feet long, 200 feet wide, with a 10-foot platform on its two sides and outer end, giving a floor space of 153,500 square feet, 24,100 square feet larger than that of the old Cunard shed.

The foundation of the land section is upon piles which carry the floor timbers direct, while in the water sections the floor is 8 feet above the cut-off of the piles. Posts being used to transfer the load of the floor to the girder caps of the piles. The pile bents are spaced 9 feet apart on centers throughout the pier.

The piles in each bent have an average spacing of 6 feet, except the pile clusters which support the columns, for which the spacing is 3 feet. The piles vary in length from 30 feet in the land section to 70 and 80 feet in the water sections, with a few lagged piles, 95 feet in length. All piles less than 50 feet in length are of chestnut, while those 50 feet and over are either oak or creosoted pine. The fender piles are 70 feet, white oak. The length is determined by the depth of water in which the pile is driven plus 20 feet which the pile is supposed to extend into the mud. The total number of piles driven under the Cunard Pier is six thousand; those in the land sections with a bearing of 9 to 15 tons per pile, and in the water sections of from 4 to 8 tons. The elevation of the floor of the pier is 20.5 feet, which is 10 feet above mean high-water in Boston Harbor. The foundation contract was let to Snare & Triest of New York. An interesting computation was made by the railroad company to determine the relative cost of a permanent concrete structure carried down to rock bottom, and the more or less temporary pile structure that was built. It was found that the interest on the enormous expenditure involved for a permanent structure far exceeded the cost of re-driving the pile foundation of the pier every twenty years or so.

During the construction of the foundation an unavoidable mistake was made. The location and operation of the water pile drivers made it desirable to drive the piles at the extremities of the bents first, and work in towards the middle. After a large portion of the piles in the first three sections had been driven, where the slope of the ground was greatest, a noticeable slide occurred from the center of the pier outward, making it necessary, in order to insure the permanence of the foundation and to guard against further slipping, to tie both sides of the pier together with steel rails, spliced together and imbedded in the concrete footings of the piers. The land slide was undoubtedly due to the compacting of the earth toward the center of the pier, by driving the outer piles first, thus causing the outward pressure to increase with each pile driven near the middle. The method taken to counteract any further slipping, though expensive in itself, was very effective. The company profited by its experience on the Cunard Pier in driving the piles of the Leyland Pier,to drive from the center outward; but took the further precaution of using an occasional tie rod to offset any tendency to move.

The superstructure of the Cunard Pier is a steel frame with side walls of corrugated asbestos, and a 2-inch plank roof with tar and slag covering. The steel work was furnished and erected by the Boston Bridge Company. The steel bents are spaced 18 feet on centers, making every alternate bent a pier bent. In each pier bent there are five columns. In the land sections these columns are supported on concrete footings carried by piles,

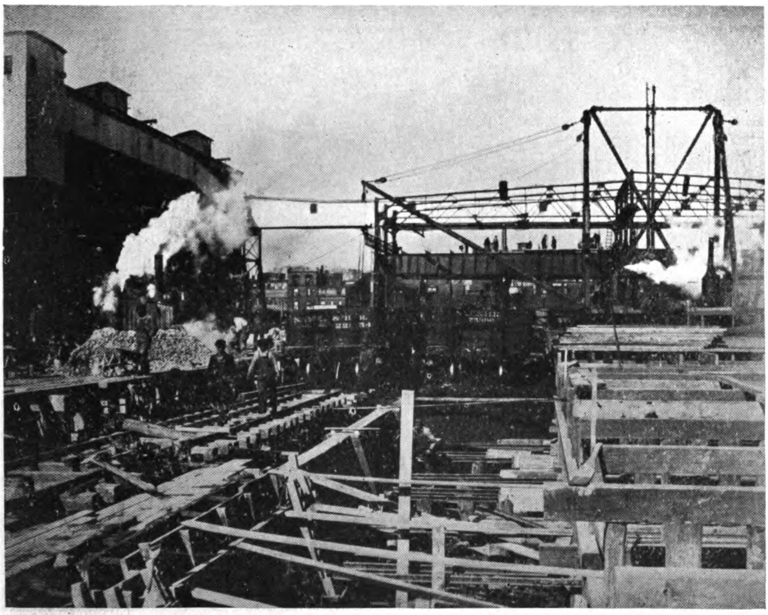


PLATE 2.

The Cunard Pier in construction, showing floor supports, rail ties, and first part of steel work.

while in the water sections they are supported upon steel grills resting on a steel grillage of timber supported by the pile caps. Under each column there are nine, and in some cases twelve, piles. The steel columns are concreted from their bases to a point 20 feet above the floor, and the steel girders carrying the passenger rooms are boxed with Egyptianite studding and Sackett plaster board. The floors consist of a 3-inch hard pine plank, ⅞ pine sheathing, and two layers of 4-ply Sackett plaster board, with a 2-inch hard pine plank for wearing surface.

Three fire walls of concrete and terra cotta separate the pier into four large sections, and extend from mean low water up through the roof. These fire walls are carried by two parallel bents of piles, 2 feet on centers, allowing the 12-inch slab to pass down between them and rest on a horizontal timber, bolted to the piles at mean low water. In these fire walls all doorways are built of hard pine, sheeted with galvanized iron, and hung on a sloping runway by a weighted chain over a pulley in which

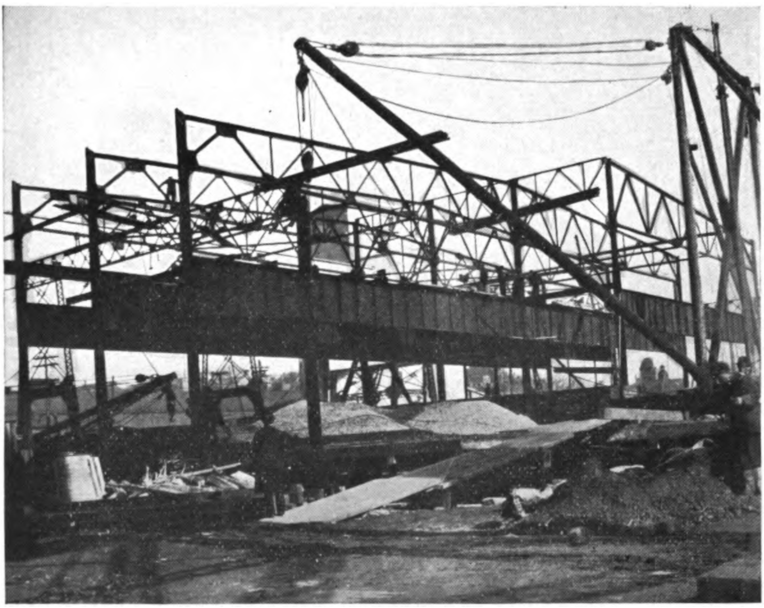


PLATE 3.

Steel Girders of new Cunard Pier for carrying floor of passenger room.

there is a fusible link, allowing the weight to drop and the door to close whenever the temperature rises to 180 degrees Farenheit.

The lower floor of the shed is devoted entirely to freight, while the passengers and baggage are all accommodated in the large rooms in the upper story. Here is ample space for distributing the baggage, separating the three classes of passengers, inspecting the third-class passengers, and feeding them during the period of their detention before they are permitted to leave the pier, or are loaded into trains for transportation West.

For fire protection 3,800 automatic sprinkler heads have been installed in the ceilings of the shed and passenger rooms, and also two monitor nozzles and two hose connections in each section, minimizing the danger from fire as much as possible.

The new Leyland Pier, slightly west of the site of the old elevator, is a structure very similar to that of the new Cunard Pier, although somewhat larger, having a floor area of 170,300 square feet. The foundation contract was let to the William L. Miller Company of Boston, and the superstructure contract to the Boston Bridge Company, and Gerry and Northrup. This

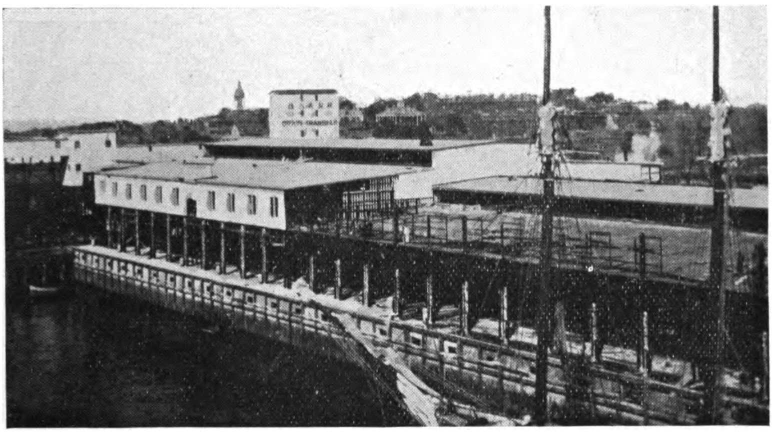


PLATE 4.

The Cunard Pier nearly completed, showing temporary elevator in rear.

pier is a one-story structure, and is leased to the Leyland Steamship Line, mainly a freight and cattle carrier with very little passenger business.

The new General Pier, of which the foundation at present is less than half completed, will be much larger than the old one. The company has secured the right from the Harbor Commissioners to change the harbor line at this point, to permit carrying this pier out to the line of the Leyland and Cunard Piers, thus getting rid of the skewed end which the old pier had Dredges at present are at work on the west side of the pier taking away the land, preparatory to driving piles for the other half. The docks between the piers are all dredged to 35 feet below mean low water, which ten feet deeper than the Boston

Harbor ship channel, thus making ample provision for increased draught for some time in the future.

The new grain elevator is placed on the north side of the yard, back from the piers, with galleries running across the yard and branching to each side of the Cunard, Leyland, and Clyde Street Piers. The Witherspoon Englar Company are the contractors as well as the engineers for this new elevator. The plans alone, furnished by this company under contract as en-

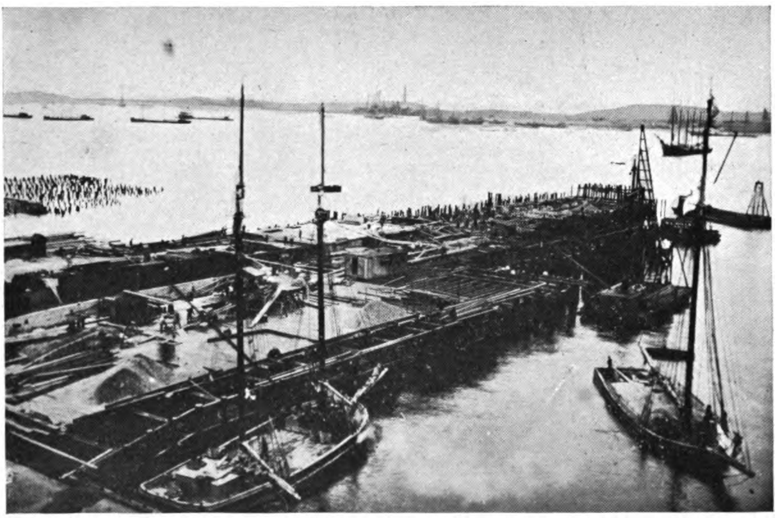


PLATE 5.

Foundation Piles of new Leyland Pier nearly all driven, bents nearly all capped and stringered, flooring of first two sections completed.
(Burned stubs of old Leyland Pier at left of picture.)

gineers, cost $30,000. The foundation of this elevator is also of piles, 25 to 30 feet in length, numbering 2,600, with a load of 18 to 21 tons per pile. The steel work alone carried by the piles weighs 4,700 tons. The superstructure of the elevator is entirely of steel, faced with brick; this steel work is at present completed only up to the top of the steel bins, of which there are 179, with a total capacity of 1,017,191 bushels.

This enlargement of the shipping facilities and improvement of their location required the entire reorganization of the company's terminal yard. The trackage has been more than doubled,

giving at present eight miles of track, with storage for 372 cars, equivalent to a train six and a half miles in length. A high-pressure water system has been installed with a 100,000 gallon water tank, the top of which is 240 feet above the level of the yard, giving a pressure of 105 pounds on the fifteen hydrants, sixteen monitor nozzles, twenty hose connections, and sixty-three hundred automatic sprinkler heads.

The total outlay of the company in East Boston amounts to nearly $6,000,000 in three years, which compares very favorably with the annual expenditures of foreign cities for water front improvements. Boston now ranks third as a shipping center in the United States, and has every chance for second place when these piers are operated to their full capacity, even though no others are constructed on the East Boston water front in the near future.

HARVARD ENGINEERS

BY CHARLES W. BAKER

(*Editor of the Engineering News, New York.*)

[A speech delivered at the joint Annual Dinner of the Association of Harvard Engineers and the Harvard Engineering Society, March 12, 1910.]

I esteem it a high privilege to be here to-night as your guest. I always enjoy meeting my brethren of the engineering profession. To-night I have the honor, not only to be among engineers but among that rare, choice, and exclusive brand known as *HARVARD* engineers.

Now possibly some matter-of-fact man, bred under some other college colors, might take exception to that. He might deny that Harvard engineers possessed any different flavor or bouquet from the engineers of some humbler vintage.

So the question arises, is there anything in a name? Have we a right to look for anything different in a Harvard man — or a Harvard engineer, if you please — from what you may find in the man from Cornell, or Michigan, or Columbia?

I shall not try to answer that question directly, except to say that with the public, — a large part of the public, — the *name* means a great deal. It is probably true that the hard-headed business man, whom you strike for a job, doesn't care a copper whether you come from Harvard or H —— Heaven. But with at least half of the public — the feminine half, I am told — Harvard is a name to conjure with.

A few days ago I was discussing with my son the question of which college he should go to. I grew a bit impatient in the discussion, and ventured the reckless statement that the colleges were all about alike, and one was as good as another. My son very promptly challenged that statement; and as I recalled my own college days, their prejudices, and their enthusiasms, I had to acknowledge there *was* a difference.

Suppose, then, that this difference exists. What ought the word "Harvard Engineer" to mean? Ought it not mean that the graduate has had all the technical training, all the engineering lore that he would receive at Renssalaer or Stevens or "Tech," plus. Plus what? Well plus, let us say, some touches of that broad culture, that familiarity with the wisdom of the ages, that love of scholarly attainments for their own sake, that knowledge of the world of books and art and science, which is always and everywhere the hallmark of "the Harvard man."

The hallmark of the Harvard man! Is it? Are you *really* doing this, you students at Harvard? The ideal is fine. What

is the reality? Yesterday one of our New York daily papers printed a statement purporting to be opinions of Harvard undergraduates about their college work. It read about like this:

> Success in college scholarship furnishes little or no indication of those intellectual qualities that men desire to possess. College is a sort of interlude in serious life, separated from what goes before and dissociated with what follows. Rank in college may be attained by aid of tutors or printed notes or "jollying" the professors. A liberal education has no bearing on the subsequent career.

Oh! So *that* is the latest Harvard interpretation of scholarship and culture and the liberal education! No, not quite the latest. I dined at a Boston hotel last night and noticed that the table was scantily supplied with dishes. I inquired the reason, and was told the china had suffered the night before from too much "Harvard culture."

And even that is not quite the latest, for in the Boston paper this morning I saw a statement by President Eliot which read: "It is not clear that education increases much the amount of common-sense which Nature gave the individual."

I read a book coming over on the train which bears directly on this question. It is written by Mr. R. T. Crane of Chicago, and is entitled "The Utility of All Kinds of Higher Schooling." In Mr. Crane's opinion the utility is *nil* or *nit*. Mr. Crane is an iconoclast. Iconoclast is a Greek word, which means "I want to smash things." I am told the Harvard freshmen are also iconoclasts. Mr. Crane wants to smash the colleges. I understand the American House proprietor feels the same way.

Really, I feel Mr. Crane's book deserves a serious word or two. I don't agree with Mr. Crane. I know he is dead wrong about many things. But there is enough of truth in his book,— enough of the opinions which are held by the world of business men,— that the colleges cannot afford to ignore it. I wish every college professor would read the book; but even more that it might be read by every college student. The Harvard students will find that Mr. Crane agrees with them in one point. He, too, declares that a liberal education is of no account as a preparation for a business life.

It is easy to criticise Mr. Crane. He wants to measure a liberal education in terms of dollars and cents. He figures how much a college boy could earn running a machine in his shop or some other manufacturer's shop, all through the years that he spends in his fitting school and in college; and he says, "Look at all that money wasted. Think of how much plumbing work that boy could have done. How many pounds of stove

polish he could have sold. How many feet of lumber he could have sawed." But Mr. Crane forgets that there are other things in life besides lumber and stove polish.

It was the hope of the great men who founded and endowed such institutions as this under whose shadow we sit that they might give to their students some clue as to the larger problems of life, some inspiration to play a large and useful part in the affairs of their fellow men.

Mr. Crane objects to spending seven years in preparing for and completing a college course, and says: "Think how much business a boy could have done in that time."

His attitude reminds me of the late Russell Sage, who made a public protest some years ago against the custom of summer vacations for employees because it was such an interruption to business!

But some of us are not living our lives solely to transact business. Neither the vacations from the daily routine of work nor the glowing memories of college days are to be weighed in the balance against the dollars that might have been.

I am far from undervaluing the element of pleasure in college life. The college years *ought* to be years when the zest of life and of attainment possesses the soul; but believe me, the men who get the greatest enjoyment from their college life are the men who are most in earnest in their college work.

I am not greatly impressed by Mr. Crane's showing of the *cost* of higher education; for the question is not what it costs but what it produces. And the question, what it produces, is one that must be answered finally by the college students themselves.

Mr. Crane alleges that the college education does not cultivate either mental ability or character, and that four years of college injure rather than benefit the majority of those who graduate from our colleges. If this were true, then, indeed, we might join in Mr. Crane's crusade. We might well, then, turn our colleges and buildings into factories and set the students to toiling inside them at real work. But Mr. Crane's indictment is not true. We know that the technical schools, as a class, are free from many of the evils that he charges. We believe that even though "the sporting microbe" has infected much of our college life, there is still a vast amount of serious, earnest work being done in our colleges.

But this is not the place or the time to discuss those tendencies in the college life of to-day which give so much concern

to all who are vitally interested in higher education. What I do want to impress upon you, Gentlemen, is the need — the urgent need — that our colleges shall actually fulfill those high purposes for which they were established. There never was greater need of men of broad education and high character than to-day. Of ordinary engineers, we have a plenty; but will you understand what I mean, when I say that there *is* need for Harvard engineers?

I spoke a while ago of the Harvard engineer as having the technical training *plus* something else. If we call that plus "polish," then let it be the polish that doesn't rub off. I hope it is something deeper than polish. I hope it is a mind alive to the larger meaning of the world. I hope it is a breadth of view, a firmness of purpose, and a patriotic devotion to public welfare, that shall make the man a power for good wherever he may go.

Our danger in America to-day is the danger of materialism. Our civilization has a surplus of wealth and a scarcity of principle. To get more money, to spend more money, and to ring all the changes on deceit, dishonor, pride, and folly in our American Vanity Fair — these are the occupations in which too many of us spend our lives. Where shall the generation that is to come after us find inspiration to better things than these? Where, indeed, if not in such temples of the higher life as this which John Harvard founded?

I do believe that even to-day, as in the past, Harvard is more, vastly more, than a mere name. I do believe that youths are to-day gaining here, as they did in generations gone, that love for the higher life, that scorn for the petty meannesses that surround us, that large comprehension of human brotherhood which lies at the foundation of a great soul.

I want to emphasize that word "brotherhood." Where in all the world should a man be valued for what he is, regardless of birth or wealth, if not in our colleges?

It has been so in the past. I am fain to believe that it is so still. Surely, if our colleges can inspire in the men who go out from them a realization of what human brotherhood and public service mean, if their hearts thrill to the sentiment "A man's a man for a' that," then in this alone the colleges make the world their debtor.

And I cannot better conclude than by saying to you that Fair Harvard was never better justified in her children than when she gave to the Nation that great crusader for true democracy, Theodore Roosevelt.

TABLE OF 1.6 POWERS OF NUMBERS

BY E. V. HUNTINGTON

Assistant Professor of Mathematics in Harvard University*

This table has been prepared for the use of electrical engineers and magneticians in the computation of the hysteretic loss of energy in cyclically magnetized iron.

The generally accepted formula for the hysteretic waste of energy in magnetized metal undergoing cyclic changes in magnetism is

$$w = \eta B^{1.6} \text{ ergs per c.c. and per cycle,}$$

where η is the "hysteretic constant" of the given metal, and B is the maximum cyclic flux density.

The first five pages of the table give the values of $x^{1.6}$ for all values of x between 1 and 10^5, correct to three significant figures, or to four significant figures when the first figure is 1, 2, or 3. (This is about the accuracy obtainable with an ordinary slide rule.)

For example, $(7640)^{1.6} = 10^6 \times 1.633 = 1{,}633{,}000$.

To obtain the value of $x^{1.6}$ for any value of x outside the range from 1 to 10^5, note that moving the decimal point FIVE places in column x is equivalent to moving it EIGHT places in the body of the table.

The seventh page contains a supplementary table from $x = 100{,}000$ to $x = 200{,}000$.

* I am indebted to one of my students, Mr. G. R. Carter, for assistance in preparing this table.

X	$X^{1.6}$	Diff.
1.0	1.000	165*
.1	1.165—	174*
.2	1.339	183*
.3	1.522	191*
.4	1.713	200*
1.5	1.913	208*
.6	2.121	216*
.7	2.337	224*
.8	2.561	232*
.9	2.793	238*
2.0	3.031	247
.1	3.278	253
.2	3.531	260
.3	3 791	27
.4	4.06	27
2.5	4.33	28
.6	4.61	29
.7	4.90	29
.8	5.19	30
.9	5.49	31
3.0	5.80	31
.1	6.11	32
.2	6.43	32
.3	6.75+	34
.4	7.09	33
3.5	7.42	34
.6	7.76	35
.7	8.11	36
.8	8.47	35
.9	8.82	37
4.0	9.19	37
.1	9.56	38
.2	9.94	38
.3	10× 1.032	38
.4	1.070	40
4.5	1.110	39
.6	1.149	40
.7	1.189	41
.8	1.230	41
.9	1.271	42
5.0	1 313	43
.1	1.356	42
.2	1.398	44
.3	1.442	43
.4	1.485+	45
5.5	1.530	

X	$X^{1.6}$	Diff.
5.5	10× 1.530	44
.6	1.574	46
.7	1.620	45
.8	1.665+	46
.9	1.711	47
6.0	1.758	47
.1	1.805+	48
.2	1.853	48
.3	1.901	48
.4	1.949	49
6.5	1.998	50
.6	2.048	50
.7	2.098	50
.8	2.148	51
.9	2.199	51
7.0	2.250—	52
.1	2.302	52
.2	2.354	52
.3	2.406	53
.4	2.459	53
7.5	2.512	54
.6	2.566	55
.7	2.621	54
.8	2 675+	55
.9	2.730	56
8.0	2.786	56
.1	2.842	56
.2	2.898	57
.3	2.955—	57
.4	3.012	58
8.5	3.070	58
.6	3.128	58
.7	3.186	59
.8	3.245—	59
.9	3.304	59
9.0	3.363	60
.1	3.423	61
.2	3.484	61
.3	3.545—	61
.4	3.606	61
9.5	3.667	62
.6	3.729	63
.7	3.792	62
.8	3.854	64
.9	3.918	63
10.0	3.981	

* To avoid interpolation in the first ten lines, one may use the "supplementary table" with proper adjustment of the decimal point.

X		$X^{1.6}$	Diff.
10.	10×	3.98	66
1.		4.64	69
2.		5.33	73
3.		6.06	76
4.		6.82	80
15.		7.62	82
6.		8.44	87
7.		9.31	89
8.	10^2×	1.020	92
9.		1.112	95
20.		1.207	98
1.		1.305—	101
2.		1.406	103
3.		1.509	107
4.		1.616	109
25.		1.725—	111
6.		1.836	115
7.		1.951	117
8.		2.068	119
9.		2.187	122
30.		2.309	124
1.		2.433	127
2.		2.560	129
3.		2.689	132
4.		2.821	134
35.		2.955—	136
6.		3 091	138
7.		3.229	141
8.		3.370	143
9.		3.513	145
40.		3.658	148
1.		3.806	149
2.		3.955+	15
3.		4.11	15
4.		4.26	16
45.		4.42	16
6.		4.58	16
7.		4.74	16
8.		4.90	16
9.		5.06	17
50.		5.23	17
1.		5.40	17
2.		5.57	17
3.		5.74	17
4.		5.91	18
55.		6.09	

X		$X^{1.6}$	Diff.
55.	10^2×	6.09	18
6.		6.27	18
7.		6 45—	18
8.		6.63	18
9.		6.81	19
60.		7 00	19
1.		7.19	19
2.		7.38	19
3.		7.57	19
4.		7.76	20
65.		7.96	19
6.		8.15+	20
7.		8.35+	20
8.		8.55+	20
9.		8.75+	21
70.		8.96	20
1.		9.16	21
2.		9.37	21
3.		9.58	21
4.		9 79	21
75.	10^3×	1.000	22
6.		1.022	21
7.		1.043	22
8.		1.065+	22
9.		1.087	22
80.		1.109	22
1.		1.131	23
2.		1.154	22
3.		1 176	23
4.		1.199	23
85.		1.222	23
6.		1.245+	23
7.		1.268	24
8.		1.292	23
9.		1.315+	24
90.		1 339	24
1.		1.363	24
2.		1.387	24
3.		1.411	25
4.		1.436	24
95.		1.460	25
6.		1.485—	25
7.		1.510	24
8.		1.534	26
9.		1.560	25
100.		1.585—	

X		$X^{1.6}$	Diff.
100.	$10^3\times$	1.585−	261*
1		1.846	276*
2		2.122	290*
3		2.412	303*
4		2.715+	317*
150.		3.032	330*
6		3.362	342*
7		3.704	36
8		4.06	37
9		4.43	37
200.		4.80	39
1		5 19	41
2		5.60	41
3		6.01	42
4		6.43	44
250.		6.87	44
6		7.31	46
7		7.77	46
8		8.23	48
9		8.71	48
300.		9.19	50
1		9.69	50
2	$10^4\times$	1.019	52
3		1.071	52
4		1.123	53
350.		1.176	55
6		1.231	55
7		1.286	56
8		1.342	57
9		1.399	57
400.		1 456	59
1		1.515+	60
2		1.575−	60
3		1.635+	61
4		1.696	62
450.		1.758	63
6		1.821	64
7		1.885+	65
8		1.950−	65
9		2.015+	66
500.		2.081	67
1		2.148	68
2		2.216	69
3		2.285−	69
4		2.354	70
550.		2.424	

X		$X^{1.6}$	Diff.
550.	$10^4\times$	2.424	71
6		2.495+	72
7		2.567	72
8		2.639	73
9		2.712	74
600.		2.786	75
1		2.861	75
2		2.936	77
3		3.013	76
4		3 089	78
650.		3.167	78
6		3.245+	79
7		3.324	80
8		3.404	81
9		3.485−	81
700.		3.566	82
1		3.648	82
2		3.730	83
3		3.813	84
4		3.897	85
750.		3.982	9
6		4.07	8
7		4.15+	9
8		4.24	9
9		4.33	9
800.		4.42	8
1		4.50+	9
2		4.59	9
3		4.68	9
4		4.77	9
850.		4 86	10
6		4.96	9
7		5 05−	9
8		5.14	10
9		5.24	9
900.		5.33	10
1		5.43	9
2		5.52	10
3		5.62	9
4		5.71	10
950.		5.81	10
6		5.91	10
7		6.01	10
8		6.11	10
9		6.21	10
1000.		6.31	

*** Interpolation at points marked (*) may be in error by two units in the last place.**

X	$X^{1.6}$	Diff.
1000.	$10^4\times$ 6.31	
1	7.35—	104
2	8.45—	110
3	9.60	115
4	$10^5\times$ 1.081	121
1500.	1.207	126
6	1.338	131
7	1.475—	137
8	1.616	141
9	1.762	146
2000.	1.913	151
1	2.068	155
2	2.228	160
3	2.392	164
4	2.561	169
2500.	2.733	172
6	2 910	177
7	3.092	182
8	3.277	185
9	3.466	189
3000.	3.659	193
1	3.856	197
2	4.06	20
3	4.26	20
4	4.47	21
3500.	4.68	21
6	4.90	22
7	5.12	22
8	5.34	22
9	5.57	23
4000.	5.80	23
1	6.03	23
2	6.27	24
3	6.51	24
4	6.75+	24
4500.	7.00	25
6	7.25+	25
7	7.51	26
8	7.76	25
9	8.02	26
5000.	8.29	27
1	8.55+	26
2	8.82	27
3	9.10	28
4	9.37	27
5500.	9.65+	28

X	$X^{1.6}$	Diff.
5500.	$10^5\times$ 9.65+	
6	9.93	28
7	$10^6\times$ 1.022	29
8	1.051	29
9	1.080	29
6000.	1.109	29
1	1 139	30
2	1.169	30
3	1.199	30
4	1.230	31
6500.	1.261	31
6	1.292	31
7	1.323	31
8	1.355+	32
9	1.387	32
7000.	1.420	33
1	1.452	32
2	1.485+	33
3	1.518	33
4	1.552	34
7500.	1 585+	33
6	1.619	34
7	1.653	34
8	1.688	35
9	1.723	35
8000.	1.758	35
1	1.793	35
2	1.829	36
3	1.864	35
4	1.900	36
8500.	1.937	37
6	1.973	36
7	2.010	37
8	2.047	37
9	2.085—	38
9000.	2.122	37
1	2.160	38
2	2.198	38
3	2.237	39
4	2.275+	38
9500.	2.314	39
6	2.353	39
7	2.392	39
8	2.432	40
9	2.472	40
10000.	2.512	40

X		$X^{1.6}$	Diff.
10000.	$10^6\times$	2.512	414*
1		2.926	437*
2		3.363	459*
3		3.822	48
4		4.30	51
15000.		4.81	52
6		5.33	54
7		5.87	56
8		6.43	58
9		7.01	60
20000.		7.61	62
1		8.23	64
2		8.87	65
3		9.52	67
4	$10^7\times$	1.019	69
25000.		1.088	71
6		1.159	72
7		1.231	74
8		1.305—	75
9		1.380	77
30000.		1.457	78
1		1.535+	80
2		1.615+	82
3		1.697	83
4		1.780	84
35000.		1.864	86
6		1.950+	88
7		2.038	88
8		2.126	91
9		2.217	91
40000.		2.308	93
1		2.401	95
2		2.496	95
3		2.591	98
4		2.689	98
45000.		2.787	100
6		2.887	101
7		2.988	102
8		3.090	104
9		3.194	105
50000.		3.299	106
1		3.405—	107
2		3.512	109
3		3.621	110
4		3.731	111
55000.		3.842	

X		$X^{1.6}$	Diff.
55000.	$10^7\times$	3.842	113
6		3.955—	12
7		4.07	11
8		4.18	12
9		4.30	12
60000.		4.42	11
1		4.53	12
2		4.65+	12
3		4.77	13
4		4.90	12
65000.		5.02	12
6		5.14	13
7		5.27	13
8		5.40	12
9		5.52	13
70000.		5.65+	13
1		5.78	13
2		5.91	13
3		6.04	14
4		6.18	13
75000.		6.31	14
6		6.45—	13
7		6.58	14
8		6.72	14
9		6.86	14
80000.		7.00	14
1		7.14	14
2		7.28	14
3		7.42	15
4		7.57	14
85000.		7.71	15
6		7.86	14
7		8.00	15
8		8.15+	15
9		8.30	15
90000.		8.45—	15
1		8.60	15
2		8.75+	15
3		8.90	16
4		9.06	15
95000.		9.21	16
6		9.37	15
7		9.52	16
8		9.68	16
9		9.84	16
100000.	$10^8\times$	1.000	

* Interpolation at points marked (*) may be in error by three units in the last place.

Supplementary Table

X	$X^{1.6}$	Diff.
100000.	$10^8\times$ 1.000	16
1	1.016	16
2	1.032	16
3	1.048	16
4	1.064	17
105000.	1.081	17
6	1.098	16
7	1.114	17
8	1.131	17
9	1.148	17
110000.	1.165—	17
1	1.182	17
2	1.199	17
3	1.216	17
4	1.233	18
115000.	1.251	17
6	1.268	18
7	1.286	17
8	1.303	18
9	1.321	18
120000.	1.339	18
1	1.357	18
2	1.375—	18
3	1.393	18
4	1.411	18
125000.	1.429	18
6	1.447	19
7	1.466	18
8	1.484	19
9	1.503	19
130000.	1.522	18
1	1.540	19
2	1.559	19
3	1.578	19
4	1.597	19
135000.	1.616	20
6	1.636	19
7	1.655—	19
8	1.674	20
9	1.694	19
140000.	1.713	20
1	1.733	20
2	1.753	19
3	1.772	20
4	1.792	20
145000.	1.812	20
6	1.832	20
7	1.852	20
8	1.872	21
9	1.893	20
150000.	1.913	

X	$X^{1.6}$	Diff.
150000.	$10^8\times$ 1.913	21
1	1.934	20
2	1.954	21
3	1.975—	20
4	1.995+	21
155000.	2.016	21
6	2.037	21
7	2.058	21
8	2.079	21
9	2.100	21
160000.	2.121	22
1	2.143	21
2	2 164	21
3	2.185+	22
4	2.207	21
165000.	2.228	22
6	2.250—	22
7	2.272	21
8	2.293	22
9	2.315+	22
170000.	2.337	22
1	2.359	22
2	2.381	23
3	2.404	22
4	2.426	22
175000.	2.448	23
6	2.471	22
7	2.493	23
8	2.516	22
9	2.538	23
180000.	2.561	23
1	2.584	23
2	2.607	23
3	2.630	22
4	2.652	24
185000.	2.676	23
6	2.699	23
7	2.722	24
8	2.746	23
9	2.769	24
190000.	2.793	23
1	2.816	24
2	2.840	23
3	2.863	24
4	2.887	24
195000.	2.911	24
6	2.935+	24
7	2.959	24
8	2.983	24
9	3.007	24
200000.	3.031	

HARVARD ENGINEERING JOURNAL

A Quarterly

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The Journal wishes again to express its appreciation of the support of the graduates, both in contributing articles and suggesting helpful changes. It feels, however, that a great stride towards better results would be made, if the graduates would

take to heart the fact that it is impossible to bring the publication to the point where it would do the most good to all interested, until they, of their own initiative, get in touch with the publishers. Suggestions, criticisms, and most of all, the contribution of articles and items of timely interest would soon make the JOURNAL of greater value to the graduates, and would be heartily welcomed by the Editor. In this connection, the attention of our readers is directed to the note of the Association, which appears below.

The attention of all graduates interested in engineering is called to the fact that the name of Mr. Edgar Conway Felton, A.B. '79, has been suggested for nomination as Overseer. Mr. Felton, who is now President of the Pennsylvania Steel Company, is a member of the Association of Harvard Engineers. The Engineering School at present has only one representative on the Board of Overseers: Mr. Howard Elliott, President of the Northern Pacific Railroad.

ASSOCIATION OF HARVARD ENGINEERS

The Association of Harvard Engineers is now entering upon its third year. While at the time of its organization, on March 21st, 1908, it had sixty-nine charter members, the membership has now increased to nearly 350, and there is every prospect of a steady growth. A complete list of the members up to the present time accompanies this issue of the JOURNAL as a supplement.

A close examination of this list will be interesting, for it will be found that the membership has wide geographical distribution. Members are now to be found in almost every state of the Union, in the Philippine Islands, the Canal Zone, and in such foreign countries as Canada, Mexico, Cuba, New South

Wales, New Zealand, etc. All branches of engineering are represented, and it will be observed that many names are those of great influence in the profession, both in the technical and executive fields.

The HARVARD ENGINEERING JOURNAL is now the official organ of this Association, and will serve it as a means of communication between all Harvard men interested in engineering, whether alumni or undergraduates. It will also serve to keep the graduates informed of the engineering activities in Cambridge, and enable them thereby to extend steadily the influence of Harvard in engineering.

The JOURNAL will be of great assistance as an auxiliary to the Registration Bureau, recently established, as a means of bringing graduates seeking employment into communication with those with employment to offer. It is hardly necessary to urge upon all Harvard men interested in engineering the desirability of coöperating with this Association, but it may be worth while to state that the most effective coöperation can perhaps be accomplished by activity in one or more of these three lines of effort:

First. Increasing the membership by bringing in other graduates and encouraging interest in the work of the Association among its members.

Second. Keeping the Registration Bureau fully informed of opportunities for employment, and the desires of employers.

Third. Writing or securing articles for the JOURNAL, and keeping its Editor posted in regard to addresses of graduates, their occupations, and other matters of current interest.

All communications for the Association and the Registration Bureau should be addressed to the Secretary-Treasurer.

F. L. KENNEDY,

Pierce Hall, Cambridge, Mass.

HARVARD ENGINEERING SOCIETY OF NEW YORK

The third regular meeting and excursion was held April 15. In the afternoon the members visited the foundation work for the new Municipal Building of New York City, under construction by the Foundation Company. Mr. Franklin Remington, President of the company, conducted the party and explained the various methods employed in sinking caissons. About fifty members attended.

The regular business meeting was held at the Harvard Club in the evening, after which Mr. T. Kennard Thomson, Consulting Engineer, gave an illustrated lecture on "Difficult Foundations," with special reference to pneumatic caissons. At the close of the lecture refreshments were served.

The next regular meeting, which will be the annual meeting with the election of officers, will be held on June 10. A special tugboat, accommodating about seventy-five, has been chartered for the afternoon excursion to the Raritan Copper Works at Perth Amboy.

HARVARD ENGINEERING SOCIETY

A joint meeting of the Society and the Harvard Mathematical Club was held on March 30 in Pierce 110. Mr. L. C. Chase spoke on "Adding Machines," using several machines as illustrations and for demonstration.

Refreshments were served after the meeting.

GEORGE W. LEWIS, *Secretary*.

HARVARD ELECTRICAL CLUB

The fifth regular meeting was held in Pierce 110 on April 7. Mr. Howard C. Forbes, Consulting Engineer, spoke on the subject of "Electric Railroads." Mr. Forbes called attention to the fact that the railroads of to-day are operated with the returns from the freight traffic as the most important consideration — the passenger traffic being merely incidental. Thus the freight service slows up the passenger schedule to an appreciable extent. According to Mr. Forbes, electric railroads should

be operated for all passenger traffic, which would result in improvement in the service because of greater safety and convenience to the passengers, higher rates of speed, and more frequent trains.

After the meeting refreshments were served.

G. L. ATKINS, *Secretary.*

HARVARD MINING CLUB

During the past eight months the active membership of the Club has been about forty-five. Seven meetings have been held, and the speakers and their subjects were as follows:

October 15. Professor H. L. Smyth spoke on "The Work of a Mining Engineer." Professor Smyth discussed the work pursued by graduates in mining from Harvard, and stated that the records showed that they were doing better work, on the whole, than graduates from other mining schools.

October 28. Professor Sauveur spoke on "The Antiquity of Iron."

November 23. This meeting was held jointly with the Technology Mining Club. Professor Richards of the Massachusetts Institute of Technology spoke on "Hindered Settling Devices."

January 7. Professor E. D. Peters spoke on "Optioning and Developing of Mine Properties."

January 20. Mr. R. V. Norris of Wilkes-Barre, Pa., spoke on "Mine Accidents."

February 23. Mr. John Greenough, President of the United Lead and Zinc Company, spoke on "Company Organization, Promotion, and Management."

March 11. Professor Raymer spoke on "Some Experiences of a Mining Engineer."

The eighth annual dinner of the Club was held in the Trophy Room of the Union at 7 P.M. on Friday, May 20. Before the dinner the election of officers for the ensuing year was held, the results being as follows: President, R. E. Somers, 1G; Treasurer, A. M. Van Rensselaer, '11; Secretary, R. P. Dunning, '11; Associates, Assistant-Professor G. S. Raymer, H. M. Bolyston, and W. S. Weeks.

About thirty members were present at the dinner. Mr. W. S. Weeks performed his duty as toast-master, and managed to get a story from nearly all of the men present. Dr. Peters and Mr. H. M. Boylston were the only members of the Faculty there, as Professor White, Professor Smyth, and Professor Sauveur, who were on the speaking list, were obliged to be absent, owing to pressing engagements. Just before the Club adjourned Mr. A. M. Van Rensselaer spoke about the plans for erecting a Club Building, but several objections to the scheme were brought forward and no definite conclusions were reached. The matter is to be taken up seriously before the end of the next year.

H. M. Kingsbury, *Secretary.*

HARVARD AERONAUTICAL SOCIETY

The seventh meeting of the Society was held in Pierce 110 on Friday, April 1. Professor I. N. Hollis spoke on "The Working of Propellers," taking up their construction and operation. This was the fourth of the series of lectures planned for the year.

The success of the design of the glider was proved by the trials early on the morning of Saturday, May 7, on Soldiers Field. Three trials were made, the glider being towed behind an automobile. During the last trial the glider remained in the air about eighteen seconds, covering about 330 feet. The easy recovery of equilibrium by means of the two stability planes in front showed their practicality, and augurs well for this feature embodied in the aeroplane. The members of the glider section expect to make free flights soon, without the tow ropes. Mr. J. V. Martin, manager of the Society, was the operator during the trials.

THE SOCIETY'S AEROPLANE

"Harvard I," the Society's first aeroplane, is now rapidly nearing completion, and will probably have had its first trial before this description is in the hands of the readers of the Journal. It is a machine of the bi-plane type, and while not

being a radical departure from the standard design, it embodies several distinct features which are the ideas of the manager of the Society, Mr. J. V. Martin. The aeroplane is a small one, its wing dimensions being only 24 by 4 feet, which give it a riding surface of 200 square feet on the main planes; in addition it has a free controlling surface of 35 square feet. The main planes are set at a distance of 4 feet apart, vertically The construction throughout is of air-dried spruce, laminated for strength, and hollowed for lightness, making it extremely strong for the weight.

A feature of the "Harvard I" is its method of control. Instead of an elevator consisting of two small planes, placed one above the other, such as is used in many machines, the machine has two small planes, placed side by side and in the same horizontal plane, capable of independent control, so that by their movements both lateral and fore-and-aft stability are attained. They are tilted by the operator, sitting just over the forward edge of the lower riding surface, who controls with his right hand the right elevator, and with his left the other. This method of control is by far the simplest yet devised, as by a single type of motion; *i.e.*, fore and aft, the operator regulates every movement vital to the stability of the machine. Turning is accomplished by a vertical plane placed in front between the elevators, and controlled by the feet of the operator.

The machine runs on a combination of skids and disappearing wheels. It will be driven by a 30 horse-power engine attached to a four-bladed Herring-Burgess propeller. Considering weight and strength, "Harvard I" is the lightest bi-plane yet designed. It is being built in the shops of the Viking Company, Cambridge, by the members of the Aeroplane Section.

The shingles of the Society, which were designed by B. Ashburton Tripp of the Architectural School, are being issued to members, and may be obtained on application to the Secretary.

EDWIN C. BROWN, *Secretary.*

THE PEN AND BRUSH CLUB

The Pen and Brush Club has sought this year to emphasize its function as the professional society of the Department of Architecture, the organization through which the desires of the students can be made known, and by which their courtesies can be extended. In fulfillment of this function, it held at the beginning of the college year a reception to new students in the department. Professor Warren, and Mr. R. W. Varney, the returning holder of the Appleton traveling fellowship, made addresses, and an exhibition of *envois* and sketches by Mr. Varney was hung in the club-room. On December 16 — in connection with the exhibition of the work of the American Academy at Rome arranged by the department — the Club tendered a reception to Mr. Harry E. Warren, a former Appleton fellow and the first holder of the Roman Prize in architecture. Mr. Warren talked of the life at the Academy and of architectural travel in the Levant and Egypt. On January 19, jointly with the Dramatic Club, the Society conducted an illustrated lecture by Mr. Frank Chanteau Brown, a Boston architect and author, editor of the *Architectural Review*, on "Stage Settings and the Modern Stage," which was followed by a smoker in the club-room. The lecture was open to the public, and was very well attended. On April 7 Mr. William D. Austin, the consulting architect of the Boston Park Commission and of the Metropolitan Park Commission, spoke on "Office Practice," illustrating the course of the design and erection of a building by a complete set of drawings for a single executed work from the first sketches to the full-size details and photographs of the finished buildings.

The annual dinner was held at the Lombardy Inn on April 26, the principal speakers being Professor Warren, Mr. Ralph Adams Cram, and Professor George Santayana.

The usual annual exhibition by the Club of work done by its members and in the department generally has been omitted this year, because its purpose has been largely fulfilled, as well as greatly supplemented, by the exhibitions held under the auspices of the department itself. These have comprised an exhibition, hung at the time of the Inauguration, of the work in architectural

design and freehand drawing; the exhibition of work of the American Academy, already mentioned; and the Intercollegiate Exhibition hung early in May.

The Society has joined with the Architectural Societies at Technology, Columbia, Cornell, and Pennsylvania, in the formation of a national body, the "Intercollegiate Architectural Federation," which it hopes will prove a medium for the exchange of ideas between the schools, and will encourage intercollegiate competitions and exhibitions.

The active membership of the Club during the year has been about twenty-five; the officers have been: President Sidney F. Kimball, '09; Vice-President Roger G. Rand, '10; Secretary Henry R. Shepley, '10 (for the first half-year), George E. Graves, '11 (for the second half-year); Treasurer David J. Witmer, '10.

SIDNEY F. KIMBALL, *President.*

GRADUATE NOTES

(On account of the many inquiries as to the whereabouts of the graduates of the department, it is hoped that the Editor will be notified of changes of address or occupation. Such notes will appear promptly in this column.)

John C. Davenport, '04, is in the Electrical Engineering Department of the Allis-Chalmers Company of Milwaukee. Address: 3326 Sycamore Street, Milwaukee, Wis.

Lawrence E. French, '07, is selling Marsh-Metz Motorcycles and Metz-Autos at 895 Main Street, Buffalo, N. Y., where he is in charge of a motor-cycle repair shop. House address: 40 Brantford Place, Buffalo, N. Y.

L. D. Granger, '04, is on the staff of the manager, Worcester District, of the American Steel and Wire Company, as metallurgist. Address: 3 Midland Street, Worcester, Mass.

Oliver S. Hills, '03, is sales engineer with the Western Electric Company, N. Y. Address: 107 Clarendon Street, Syracuse, N. Y.

Joseph Husband is with Stone & Webster. Address: 604 First National Bank Building, Chicago, Ill.

Sidney J. Jennings, '85, is vice-president of the United States Smelting, Refining, and Mining Company. Address: 42 Broadway, N. Y.

Chester H. Lehman, '09, is advertising manager for the Blaw Collapsible Steel Centering Company, makers of steel forms for subway, aqueduct, sewer, tunnel, and similar concrete construction. Address: Westinghouse Building, Pittsburg, Pa.

Edward L. Lincoln, '08, is a resident assistant engineer with the New York Board of Water Supply. Address: Care Young Men's Christian Asociation, White Plains, N. Y.

Wisner Martin, '90, architect and engineer, is designing and supervising engineer of the new factory building for Rice and Hutchins, Inc., at South Braintree, Mass. It is 50 feet by 260 feet, five stories high, with an office and shipping wing 42 feet by 50 feet, three stories high, and a tower 100 feet high which supports a 15,000 gallon water tank to supply the sprinkler system. It is all reinforced concrete, with brick curtain walls, girderless floors, and saw-tooth roof. His address is 50 Highland Avenue, Cambridge, Mass.

Arthur H. Morse, '01, is mechanical engineer with the Baldwin Piano Company, Cincinnati, Ohio.

Mason T. Rogers, '08, is about to become a hydrographer under the Isthmian Canal Commission, and will be located at Panama. Permanent address as before: 63 5th Avenue, New York City.

Harris E. Sawyer, '91, chemical engineer, holds an appointment in the Department of Agriculture, Washington, D. C., as expert on the technology of the fermentation industries. At present he is on extended leave learning the practical side of farming. Address: East Andover, N. H.

Karl D. Schwendener, '08, is a draughtsman on the Los Angeles Aqueduct. Address: 135 South Grand Avenue, Los Angeles, Cal.

R. E. Scott, '07, is with the engineering department of the National Electric Lamp Association, Cleveland, Ohio, and is engaged in technical publicity work. Mr. Scott is the author of a number of articles on Illuminating Engineering, two papers on "The Electric Lighting of Automobiles" in the *Illuminating Engineer* being among his recent publications. Address: 1910 East 55th Street, Cleveland, Ohio.

Allan B. Souther, '97, is teaching descriptive geometry and mechanical drawing; he is also engaged in the scrap iron and metal business. Address: 1211 Mulberry Street, Baltimore, Md.

B. Ashburton Tripp, Sp., is studying city planning with Professor Olmstead. He will return to college in the fall to resume work in landscape architecture. Address: Keystone Building, Pittsburg, Pa. Mr. Tripp drew the seal for the Aeronautical Society which was published in the last issue, and recently completed a design for the shingle of the same society, which is being issued to members.

MISCELLANEOUS NOTES

Appointments

Louis Caryl Graton, assistant professor of Mining Geology, from September 1, 1910. *(Consent given by Board of Overseers April 13, 1910.)*

S.B. *(Cornell University)* 1900. Mining Geologist, United States Geological Survey; Instructor in Mining Geology, 1909-10, Harvard University.

Edward Vermilye Huntington, assistant professor of Mathematics, from September 1, 1910. *(Consent given by Board of Overseers April 13, 1910.)*

A.B. *(Harvard)* 1895; A.M. *(ibid.)* 1897; Ph.D. *(Strassburg)* 1901; Instructor in Mathematics, 1895-97, 1901-05; Assistant Professor of Mathematics, 1905-10, Harvard University.

Lecturers for one year from September 1, 1910:

Ralph Adams Cram, F.A.I.A. *(Architectural Design).*
Professor Desire Despradelle, Massachusetts Institute of Technology *(Architectural Design).*
James Ralph Finlay, A.B. *(Economics of Mining).*
Robert Van Arsdale Norris, E.M. *(Coal Mining).*
Thomas Arthur Rickard, A.R.S.M. *(Mining Geology).*
Arthur Truman Safford, A.M. *(Hydraulic Engineering).*

Instructors for one year from September 1, 1910:

Harold Gilliland Crane, S.B. *(Electrical Engineering).*
Henry Atherton Frost, A.B. *(Architectural Design).*
Edward Russell Markham *(Shopwork).*
John Robert Nichols, A.B. *(Civil Engineering).*

Clifton Harlan Page, B.A.S. *(Civil Engineering).*
Eliot Twing Putnam, A.B. *(Architectural Design).*
Harold Broadfield Warren *(Architectural Design).*
Walter Scott Weeks, A.B., S.B., M.E. *(Mining and Metallurgy).*

Austin Teaching Fellows, for one year, from September 1, 1910:
Richard Rich Freeman, Jr., A.B. *(Mining and Metallurgy).*
Hector Macdonald Kingsbury *(Mining and Metallurgy).*

Assistants, for one year, from September 1, 1910:
Herbert Melville Boylston, S.B., A.M. *(Metallurgy and Metallography).*
George Falley Ninde *(Drawing and Machine Design).*

John W. Davis, '10 *(Cornell),* in Mechanical Engineering, is to be one of the assistants in the Electrical Department of the Graduate School of Applied Science for 1910-11.

Additions and Changes in Courses of Study

Engineering 6D will in the future precede Engineering 6C, and the subject matter of the courses will be rearranged,— steam flow and kindred subjects being transferred from 6C to 6D, and more time being given in 6C to sewage and waste disposal.

A course in "Photometry and Illumination," Engineering 16B², has been given by Professors Clifford and Kennelly.

Engineering 20N, a research course in "Mechanical Refrigeration." has been given by Professor Marks.

Professor H. E. Clifford spoke at the Coast Artillery School, Fortress Monroe, April 5, on "Graduate Work in Applied Science." On April 9 he spoke at the Bureau of Standards, Washington, D. C., on "Science in Engineering."

Professor I. N. Hollis will deliver the Commencement Address at the Worcester Polytechnic Institute in June.

Professor A. E. Kennelly gave an address at Schnectady, N. Y., to the Schnectady Section of the American Institute of Electrical Engineers April 12 on "Wireless Telegraphy and Telephony." On March 12 he spoke to the graduate class of the Annapolis Naval Acadamy on "The Operation of Motors from Central Power Plants."

Professor G. F. Swain spoke at the opening of the new engineering building at Union University, Schnectady, N. Y., April 28, on "Limitations of Efficiency in Engineering Education."

Among *recent publications* by members of the staff were:

"Forests and Stream Flow," by Professor G. F. Swain. *American Forestry Magazine,* April, 1910; and *Engineering News,* April, 1910.

"Union College Address," by Professor G. F. Swain, *Engineering News,* May 14, 1910.

The new standardizing laboratory, which will be ready for the regular work of the Department of Electrical Engineering at the opening of the fall term, is fast nearing completion, and much of the apparatus has been purchased or is already ordered.

An Ingersoll-Rand two-stage air compressor, driven by a compound steam engine, and capable of handling 150 cubic feet of free air per minute and discharging it against a pressure of 250 pounds per square inch, has been added to the Mechanical Engineering Laboratory. This compressor will be very useful both as a field for investigation and also for supplying compressed air for various purposes. It is being used at present in connection with some gas engine research.

George Fox, a special student in the Graduate School of Architecture, 1909-10, won second prize in the competition for the Rotch Traveling Scholarship in Architecture.

Sidney Fiske Kimball, now in the Graduate School of Architecture, won the prize offered by the Boston Society of Architects for the best architectural design.

BOOK REVIEWS

Bridge and Structural Design, by W. Chase Thomson, member Canadian Society Civil Engineers; assistant engineer, Dominion Bridge Company, Montreal Canada. *Engineering News Publishing Company,* New York, 1910. $2.50, net.

This little book of 192 pages is stated by the author to be intended principally for students and draughtsmen, and to be the outcome of lectures given by him, under the auspices of the Dominion Bridge Co., presumably to employers of the company.

It covers, necessarily in superficial manner, the whole range of the subject, from the definitions and first principles of mechanics to the design of a highway bridge with a span of 120 feet. To cover this range within the compass of 192 pages requires the utmost brevity, and does not allow a full discussion of the subject. No calculus is used, and only uniform loads are considered.

The first chapter of 16 pages outlines the principles of mechanics, comprising simply the principle of the composition of forces and its application to simple trusses, together with the law of the lever. The shearing and bending stresses are treated in the second chapter (26 pages), and the deflection of beams in the next chapter (14 pages). Columns and struts are next discussed (11 pages), then the loads on structures, and riveting (10 pages). The remainder of the book is entirely taken up with numerical examples of design, the structures worked out being: a small office building, a simple roof truss, a roof truss on steel columns, a flat girder, a fifty-foot riveted highway bridge, and a 120-foot pin-connected highway bridge. In the last chapter tables of coëfficients are given, by which the stresses in Pratt and Warren trusses may be obtained.

It would be invidious to point out omissions in so brief a book as this, which is only an outline. Neither is it necessary to refer to a few inaccuracies which have crept in, as, for instance, in the treatment of earth pressure. The book, however, notwithstanding its brevity, contains a great deal of instructive matter, and it may be studied with much profit by students and draughtsmen, for whom it was designed; and even graduates of our technical schools would derive much benefit by working through the examples. It will help them to clarify the ideas they have gained by their more thorough course.

The author's discussions are generally sound, and show the possession of much commonsense, and of experience in the subjects he treats. In reality these subjects are simple, and depend only upon the most elementary mechanical principles, and there is no need of obscuring them, as some writers do, under a mass of mathematical complexity.

On the other hand, the student who has worked through this book must not deceive himself by imagining that he therefore understands bridge design thoroughly. He must prepare himself by a much more thorough study of mechanics and its applications to structures, before he can intelligently meet the conditions which almost every problem brings before the designing engineer.

G. F. Swain,
Professor of Civil Engineering.

THE FIELD PRACTICE OF RAILWAY LOCATION, by Willard Beahan, division engineer, Chicago & Northwestern Railway. *Engineering News Publishing Company,* New York, 1909. $3, net.

This book of 254 pages is a useful and interesting record of methods used in the West, during the past decade, in railroad location. The character of road, that present and predicted conditions would economically demand, is well and sanely treated. The chapters on reconnaissance for route, geology and its relation to topography and the preliminary survey, with excellent sketches, are the features of the book. Sufficient space is devoted to train resistance, the locomotive, grade and curve resistance, and cost of construction to enable the locating engineer to make an economical final location.

The book contains much practical and first-hand information. It will help the young engineer over many of the difficulties encountered on his first location, as well as furnish valuable information as to organization, care, and equipment of field parties.

J. C. BARNES,
Second General Assistant, Harvard Engineering Camp.

A HISTORY OF THE LOGARITHMIC SLIDE RULE AND ALLIED INSTRUMENTS, by Florian Cajori, Professor of Mathematics and Dean of the School of Engineering, Colorado College, Colorado Springs, Colo. *Engineering News Publishing Company,* New York, 1908. 126 pp. $1, net.

This is a very complete history of the development of slide rules from Gunter's "logarithmic line" of 1620, with its inseparable pair of compasses, to the perfected and often highly ingenious and complicated forms of the present day. It goes much into detail, too much probably to interest most engineers. It is nevertheless well written, and any user of slide rules who happens also to have a taste for historical research will find it worth reading. Seventeen illustrations, many of them half-tone reproductions from early descriptions, add to its attractiveness.

One of the most astonishing things presented in the book is a thirty-two page list of two hundred and fifty-six different slide rules which have been used or described since 1800. Of course many of these are merely the slightly varying forms in which different makers have supplied essentially the same standard device, but a surprisingly large number, especially of the later ones, are more complicated rules which have been made for special kinds of computation, such as gauging, the computation of annuities, the strength of gear, the flow of water, various powers and roots, etc., etc. Among the simplest of these are the "duplex" and "log log" rules now coming somewhat into favor, but there are also stadia rules, shaft, beam and girder scales, pump scales, wiremen's scales, sewer computers, and so many other forms, that it would seem to be worth while for a practising engineer, when once he has chosen his special field, to make a systematic search for mechanical aids in his routine computations. As Benoit is quoting as saying of the ordinary rules in its early days: "It is the experience of all that skill in the use of the rule is not attained, except as the result of considerable practice. But once this skill is acquired, the instrument is loved, and used persistently."

H. N. DAVIS,
Instructor in Physics and Mathematics.

TABLES AND DIAGRAMS OF THE THERMAL PROPERTIES OF SATURATED AND SUPERHEATED STEAM, by L. S. Marks, M.M.E., Professor of Mechanical Engineering; and H. N. Davis. Ph.D., Instructor in Physics and Mathematics, Harvard University. Longman, Green & Co., New York, 1909. $1, net.

This book is rather more than its title implies. In addition to the steam tables and diagrams and an unusual amount of explanatory matter, it contains other tables of value and a section giving a very complete "discussion of sources" which, aside from its intrinsic value, gives evidence of the great care exercised in preparing the book.

The evidence regarding the reliability of the data employed in computing the tables is convincing; the computation and checking has evidently been done with great care; and the proof-reading has apparently been unusually effective since, after using the book for a year, the writer has noted but one insignificant typographical error.

The tables themselves are complete and especially well arranged for accurate and quick use. While compact, the grouping of the figures makes the page easily read, and this is still further aided by the unusually clear character of the type employed and the sharp impression taken by the paper. The table of "superheated steam," one especially difficult to arrange, has been handled with success. The idea of printing useful data at the bottom of the pages is a good one, while another good feature is the fine group of conversion tables, which are unusually complete, and well arranged for easy reference.

The tables are supplemented by diagrams, plotted to a convenient scale, which enable quick computations to be made. These are of such value that it might be well to mount them on linen so that they could be more readily and roughly handled.

The section on "discussion of sources" is concise, complete, and, as already noted, convincing. It forms an unusual and valuable addition to the collection of tables.

This combination of effort on the part of two authors representing the viewpoint of both pure and applied science carries with it the evidence of its reliability, while its actual use has proven its usefulness.

WM. H. KENERSON,
Associate Professor of Mechanical Engineering,
Brown University.

ASSOCIATION OF HARVARD ENGINEERS

ORGANIZED MARCH 21, 1908

LIST OF MEMBERS

SUPPLEMENT TO HARVARD ENGINEERING JOURNAL
MAY, 1910

OFFICERS

ELECTED MARCH 12, 1910

PRESIDENT

BERNARD R. GREEN, S.B. 1864 — Washington, D.C.
Supt. Buildings and Grounds, Library of Congress

VICE-PRESIDENTS

CHARLES P. STEINMETZ, (Hon.) A.M. 1902 — Schenectady, N.Y.
Consulting Eng'r, General Elect. Co.; Professor Elect. Eng'g, Union Univ.

FRANCIS W. DEAN, S.B. 1875 — Boston, Mass.
Mill Eng'r and Architect

BENJAMIN B. THAYER, C.E. 1885 — New York City
President, Anaconda Copper Mining Co.

SECRETARY-TREASURER

F. L. KENNEDY, A.B. 1892; S.B. 1898 — Cambridge, Mass.
Assistant Professor of Drawing and Machine Design, H. U.

MEMBERS OF COUNCIL

(Three Years)

A. W. K. BILLINGS, A.B. 1895; A.M. 1896 — New York City
Eng'g Manager, J. G. White & Co., Inc.

LEWIS J. JOHNSON, A.B. 1887; C.E. 1888 — Cambridge, Mass.
Professor Civil Eng'g, H. U.

(Two Years)

PHILIP W. DAVIS, A.B. 1893; S.B. 1895 — Boston, Mass.
Consulting Engineer

JAMES F. SANBORN, S.B. 1899 — Peekskill, N.Y.
Div. Eng'r, Board of Water Supply

(One Year)

E. C. FELTON, A.B. 1879 — Philadelphia, Pa.
President of Pennsylvania Steel Company

FRANKLIN REMINGTON, A.B. 1887 — New York City
President of the Foundation Company, New York

CONSTITUTION

ARTICLE I

Name

The name of this organization shall be the Association of Harvard Engineers.

ARTICLE II

Object

The object of this Association shall be to advance the cause of Engineering, including kindred professions; to increase the influence and usefulness of Harvard in Engineering; and to promote mutual acquaintance and good fellowship among members of the Association:

1. By development of organization among Harvard men in Engineering.
2. By encouragement and assistance to Harvard University in behalf of Engineering.
3. By encouraging and assisting in the formation and growth of local organizations of Harvard men interested in Engineering.

ARTICLE III

Membership

Section 1. — Membership shall be open to any former member, past or present officer, or any honorary degree holder of Harvard University, whether educated in Engineering at Harvard or elsewhere, who is identified professionally, or associated as owner or director with Engineering in any of its branches and who wishes to coöperate with the purposes enumerated in Article II.

Sec. 2. — Honorary members may be elected by this Association on nomination by the Council.

ARTICLE IV

Election of Members

Section 1. — To become a member a candidate must apply in writing, must be endorsed by two members of the Association and receive the approval of the Council. A majority of the Council shall elect to membership.

SEC. 2. — Members elect shall be notified of their election by the Secretary. Upon payment of the membership fee for the current year they shall become members.

ARTICLE V

Dues

SECTION 1. — The annual dues shall be $1.00, payable on or before Commencement Day.

SEC. 2. — By payment of $10.00 at one time, a member may become a life member.

SEC. 3. — Members whose dues are in arrears for more than one year may be dropped by a majority vote of the Council.

ARTICLE VI

Officers

The officers of this Association shall be a President, three Vice-Presidents, a Secretary-Treasurer, and a Council consisting of the foregoing officers *ex-officio* and six other members.

ARTICLE VII

Terms of Office

SECTION 1. — The President, Vice-Presidents, and Secretary-Treasurer shall be elected for a term of one year.

SEC. 2. — The members of the Council not members *ex-officio* shall be elected as follows: at the first meeting of the Association two members shall be elected for a term of one year, two members for a term of two years, and two members for a term of three years; and thereafter at the annual meeting of the Association two members shall be elected for the full term of three years, to fill the place of members whose term of office shall have expired.

SEC. 3. — Vacancies occurring in the Council before the expiration of their respective terms of office shall be filled at the annual meeting next following the occurrence of such vacancies, but until such a meeting the vacancy shall be filled by the remaining members of the Council.

SEC. 4. — All officers of the Association shall hold their respective offices during the regular term thereof and until their successors shall be elected and qualified.

SEC. 5. — Ex-Presidents of the Association shall continue members of the Council for three years from the date of expiration of their term of office.

ARTICLE VIII

Duties of Officers

President

Section 1. — The President shall preside at all meetings of the Association and of the Council. In the absence of the President, a Vice-President shall perform the duties of the President.

Secretary-Treasurer

Sec. 2. — The Secretary-Treasurer shall, in addition to the duties usually appertaining to the office of Secretary, receive all dues and care for the funds of the Association. He shall pay all expenses authorized by the Council. At the annual meeting or any other meeting, upon request of the Council, he shall make a complete report upon the finances of the Association. He shall have his headquarters in Cambridge or Boston. He shall maintain a card index of the names, addresses, and professional record of all Harvard Engineers, whether or not members of the Association. He shall keep in touch with local organizations which may be formed and with the Harvard Engineering Society at Harvard, and see that transactions of interest to the members of the Association are published in the *Bulletin* and in other papers or periodicals when conditions justify such publication. The detail work of the development of organization among Harvard Engineers shall be done mainly by the Secretary-Treasurer. He may receive compensation at the discretion of the Council.

Council

Sec. 3. — The executive power of the Association shall be vested in the Council, subject to the control and direction of the Association. It shall arrange for all meetings, authorize all expenditures, pass upon all candidates for membership, and otherwise act for the Association on all matters requiring action between meetings of the Association.

ARTICLE IX

Corresponding Secretaries

Section 1. — The Council shall have the power to appoint from time to time one or more Corresponding Secretaries in the different cities or towns of the world. It shall be the duty and office of such Corresponding Secretaries to promote in their respective localities the objects and interests of the Association, and if possible to organize local Harvard Engineering Societies.

Quorum

Sec. 2. — The Council shall fix the number of members of the Association necessary to constitute a quorum for transaction of any and all business, save that of amending the Constitution, and to fix also the number of their own members necessary to constitute a quorum of the Council.

ARTICLE X

Election of Officers

The officers of the Association shall be elected at the annual meeting by letter ballot. The Council shall elect a Nominating Committee of three, not officers of the Association, who shall furnish the Secretary at least six weeks prior to the annual meeting a list of candidates for the offices to be filled. The Secretary shall mail to each member of the Association, at least four weeks prior to the annual meeting, a notice thereof and a printed ballot containing the names proposed by the Nominating Committee, with blank spaces for the insertion of alternate names.

ARTICLE XI

Meetings

Section 1. — The annual meeting of the Association shall be held in Cambridge or Boston, Massachusetts, at a time to be fixed by the Council.

Sec. 2. — The annual meeting may be accompanied by a dinner, if deemed expedient by the Council, in which case the members of the Harvard Engineering Society at Harvard shall be invited to attend upon the same terms as members of the Association.

Sec. 3. — The Council shall have the power to call a special meeting of the Association at any time, provided that at least two weeks previous notice in writing be given to all members of the Association.

ARTICLE XII

Amendment to Constitution

This Constitution may be amended by a majority vote of all members of the Association present at the annual meeting or any special meeting called for that purpose, provided the proposed amendment in substance, signed by five members, is presented to the Secretary at least six weeks prior to the meeting. The proposed amendment shall be printed and sent to all members, together with the notice of meeting.

LIST OF MEMBERS

Adams, Comfort Avery, (*Case Sch. App. Sc.*, S.B. 1890; E.E. 1905) (C. L. 1908)
Prof. Elect. Eng'g, H.U. 13 Farrar St., Cambridge, Mass.

Adams, Kilburn Elie, A.B. 1902; S.B. 1903 (C. 1908)
Mech. Eng'r, Boston & Albany R.R.
Room 372, So. Station, Boston, Mass.
and 123 Oxford St., Cambridge, Mass.

Alden, Frederick Arthur, A.B. 1905; S.B. 1907 (C. L. 1908)
Chief Eng'r with McLean & Cousens, Eng'rs & Contractors
204 Purchase St., Boston, Mass.
and 60 Gorham St., Cambridge, Mass.

Alderson, Victor C., A.B. 1885 (1909)
Pres., Colo. School of Mines Golden, Colo.

Anderegg, Gustavus Adolphus, A.B. 1900; A.M. 1902 (1908)
Elect. Eng'r, Western Electric Co. 463 West St., N.Y. City

Arnold, Chester H, A.B. 1892; A.M. 1893 (1908)
Elect. Eng'r with American Tel. & Tel. Co. 15 Dey St., N.Y. City

Arnold, Louis, A.B. 1855; S.B. 1858 (1908)
Elevator Eng'r 176 Park St., West Roxbury, Mass.

Baldwin, James Rumford, S.B. 1905 (L. 1908)
Civil & Hydraulic Eng'r
Care of Turner's Falls Co., Turner's Falls, Mass.

Bard, Darsie Campbell, A.B. 1903 (1908)
Mining Eng'r 436 Phoenix Block, Butte, Mont.

Barklage, Walter Frederick, S.B. 1906 (1909)
International Supply & Export Co. St. Louis, Mo.
and 5139 Morgan St., St. Louis, Mo.

Barnard, Roger Conant, A.B. 1902 (1908)
Eng'r, Westinghouse, Church, Kerr & Co. 10 Bridge St., N.Y. City
and 30 Shaw St., West Newton, Mass.

C., Charter Member.
L., Life Member.
(1908), Joined Association in 1908.

BARRETT, Nelson Macy, A.B. 1887 (1908)
Canal Construction (Dept. of Motive Power & Machinery)
Culebra, Canal Zone, Panama.

BARRETT, Robert Edward, Sp. 1905 (1908)
Ass't Eng'r, Designer, B'd Water Supply N.Y. City

BARTLETT, Henry, A.B. 1885 (1909)
Gen'l Mech. Sup't, B. & M. R. R. Boston, Mass.
and 51 Highland St., Cambridge, Mass.

BATCHELDER, William Osgood, S.B. 1905 (1908)
Elect. Eng'r 204 Lafayette St., Salem, Mass.

BEGIEN, Ralph Norman, 1897 (1908)
Division Eng'r, B. & O. R. R. Philadelphia, Pa.

BELCHER, Wallace Edward, A.M. 1904 (1909)
Structural & Hydraulic Eng'r, with H. M. Byllesby & Co.
Chicago, Ill.

BIGELOW, William DeFord, A.B. 1900 (1908)
Building Contractor, Bigelow & Harriman 127 Federal St., Boston
and Cohasset, Mass.

BILLINGS, Asa White Kenney, A.B. 1895; A.M. 1896 (L. 1908)
Eng'g Mgr., J. G. White & Co., Inc. 43 Exchange Place, N.Y.City

BLAKE, Edmund Mortimer, S.B. 1899 (1908)
Cons. Eng'r, Blake & Symonds Boise, Id.

BLAKE, Robert Fulton, S.B. 1899 (1910)
With Eng. M. & C. Submarine Signal Co.
212 Beacon St., Boston, Mass.

BLYE, Joseph Napoleon, S.B. 1896 (1908)
143 Liberty St., N.Y. City

BOOTH, William F., C.E. 1884 (1908)
Clerk U. S. Custom House, N.Y. City

BOOTH, William Miller, S.B. 1893 (1908)
Consulting Eng'r and Chemist 712 Dillaye Bldg., Syracuse, N.Y.

BOYLSTON, Herbert Melville, S.B. 1903; A.M. 1905 (L. 1910)
Metallurgical Eng'r and Teacher
Rotch Bldg., H.U., Cambridge, Mass.

BRINTON, Willard Cope, S.B. 1907 (L. 1908)
Industrial Eng'r
Westinghouse Elect. & Mfg. Co. East Pittsburg, Pa.

C., Charter Member.
L., Life Member.
(1908), Joined Association in 1908.

BROOKS, Alfred Hulse, S.B. 1894 (1908)
Geologist in Charge, Div. Alaskan Mineral Resources
U. S. Geological Survey, Washington, D.C.

BROWN, Albert Frederick, S.B. 1890 (C. 1908)
36 Maxwell St., Dorchester Centre, Mass.

BROWN, Edwin Hacker, A.B. 1896 (*W.P.I.*, S.B. 1898) (1908)
With Caldwell and Brown Co., Power Machinery
1047 Security Bank Bldg., Minneapolis, Minn.

BUCKE, John H., S.B. 1906 (C. 1908)
Ass't Elect. Eng'r 74 Maplewood Ave., Pittsfield, Mass.

BURDEN, James Abercrombie, Jr., A.B. 1893 (L. 1908)
Pres., Burden Iron Co. Troy, N.Y.

BURGWYN, Collinson Pierrepont Edwards, A.B. 1873; C.E. 1876
(1908)
Civil and Hydraulic Eng'r 917 Bank St., Richmond, Va.

BURKE, Albert G., Jr., 1903 (1909)
District Mgr., Green Eng'g Co.
1222 Farmer's Bank Bldg., Pittsburg, Pa.

BURKE, Walter Safford, Ass't Prof. Mech. Eng'g, 1899–1904, H.U.
(C. 1908)
Inspector Grounds & Bldgs., H. U.
Consulting Eng'r, Burke & Hughes
15 Lake View Ave., Cambridge, Mass.

BURNS, James Dennis, S.B. 1903 (C. 1908)
4 Webb St., Salem, Mass.

BURR, William Hubert (*Rens. Pol. Ins.*, C.E. 1872) (L. 1908)
Prof. Civil Eng'g, Columbia Univ., Consulting Eng'r
Columbia Univ., N.Y. City

CABOT, Walter Kinsman, S.B. 1907 (C. 1908)
Elect. Eng'r, Western Elect. Co. 463 West St., N.Y. City
and 16 Ellsworth Ave., Cambridge, Mass.

CAMPBELL, George Ashley, A.B. 1892; PH.D. 1901 (L. 1908)
Research Eng'r, Amer. Tel. & Tel. Co. 15 Dey St., N.Y. City

CARTER, Carroll Martin, A.B. 1894 (1908)
Mining Ohio City, Col.
and 1430 Vine St., Denver, Col.

CHACE, Carll Smith, S.B. 1905 (C. 1908)
Engineer 31 Wales St., Dorchester, Mass.

C., Charter Member.
L., Life Member.
(1908), Joined Association in 1908.

CHENEY, Herbert Neal, S.B. 1899 (1908)
Eng'r in charge, Calf Pasture Station, Boston Consol. Gas Co.
and 212 Savin Hill Ave., Dorchester, Mass.

CHICKERING, Tileston, S.B. 1902 (1909)
With Carnegie Steel Co. 244 So. Highland Ave., Pittsburg, Pa.

CHITTENDEN, Albert Percival, A.B. 1897; A.M. 1898 (1908)
Mining Eng'r, Operator, Promoter 53 State St., Boston, Mass.
and Hotel Beaconsfield, Brookline, Mass.

CLARK, Thomas Roy, S.B. 1904 (1908)
T. R. Clark & Co., Oil Producers
Bradford Nat'l Bank Bldg., Bradford, Pa.

CLARK, Thomas Welcome, S.B. 1898 (1908)
Ass't Eng'r Care Great Northern Paper Co., Millinocket, Me.

CLARK, William Edwin, S.B. 1895 (C. 1908)
Electrical Contractor 543 Boylston St., Boston, Mass.

CLARK, William Moulton, S.B. 1903 (L. 1908)
Mining Eng'r 40 James St., Ansonia, Conn.

CLARKE, Edmund Arthur Stanley, A.B. 1884 (L. 1908)
President, Lackawanna Steel Co. 2 Rector St., N.Y. City

CLARKE, John Gray, S.B. 1898 (L. 1908)
Supt., Warren Bituminous Paving Co. Toronto, Ont.
and 20 High St., Southbridge, Mass.

CLIFFORD, Harry Ellsworth (*M.I.T.*, S.B. 1886) (1909)
Prof. Elect. Eng'g, H. U. Pierce Hall, Cambridge, Mass.

COFFIN, Francis Parkman, S.B. 1903 (C. 1908)
With General Elect. Co. 18 Rugby Rd., Schenectady, N.Y.

COGSWELL, Edward Russell, Jr., A.B. 1897 (1908)
Landscape Architect 67 Chester St., Newton Highlands, Mass.

COLE, Charles Briggs, S.B. 1867 (1908)
Railroading Chester, Ill.

COOLIDGE, William Henry, A.B. 1881 (1908)
Lawyer 50 Congress St., Boston, Mass.

COUTANT, John Karlton, S.B. 1906 (1909)
Eng'r with Westinghouse Elect. & Mfg. Co. Newburg, N.Y.

CRIMMINS, Thomas, S.B. 1900 (L. 1909)
Contractor 444 East 69th St., N.Y. City

C., Charter Member.
L., Life Member.
(1908), Joined Association in 1908.

CROSSE, Shirley Robbins, S.B. 1906 (C. 1908)
With Stone & Webster Management Ass'n
147 Milk St., Boston, Mass.
and 23 Dickerman Rd., Newton Highlands, Mass.

CUNNINGHAM, Stanley, A.B. 1901; S.M. 1902 (1910)
Eng'r and Architect 11 E. 24th St., N.Y. City

DANIELSON, Whitman, A.B. 1904; S.B. 1906 (1908)
Elect. Eng'r Putnam, Conn.

DAVIS, Philip Whitney, A.B. 1893; S.B. 1895 (C. L. 1908)
Engineer 110 Irving St., Cambridge, Mass.

DAVOL, Frank Herbert, Jr., S.B. 1903 (L. 1908)
Estimator, Amer. Car & Foundry Co. 165 Broadway, N.Y. City
and 75 Remsen St., Brooklyn, N.Y.

DAY, Paul, S.B. 1896 (C. 1908)
Lumber Business Blaine, Wash.

DEAN, Arthur Lyman, A.B. 1900 (1908)
Ass't Prof. Industrial Chemistry
Sheffield Scientific School, New Haven, Conn.

DEAN, Francis Winthrop, S.B. 1875 (C. L. 1908)
Mill Eng'r and Architect 53 State St., Boston, Mass.

DELANO, Frederic Adrian, A.B. 1885 (L. 1909)
Pres., Wabash R. R. 510 Wellington Ave., Chicago, Ill.

DELANO, Warren, S.B. 1873 (C. L. 1908)
Coal Operator 1 Broadway, N.Y. City

DENSMORE, Edward Dana, S.B. 1894 (*M.I.T.*, S.B. 1893) (L. 1908)
Consulting Eng'r, Densmore & LeClear
88 Broad St., Boston, Mass.

DEVONSHIRE, Charles Edwin, S.B. 1907 (L. 1908)
2 Sargent St., Dorchester, Mass.

DEWEY, George Chauncey, 1892 (1909)
Mining Wheeling, W. Va.

DOW, Carl Stephen, S.B. 1897 (1909)
Publicity Eng'r with Walter B. Snow Boston, Mass.
and 24 Milton Sq., Hyde Park, Mass.

DOYEN, George Evelyn, S.B. 1907; C.E. 1908 (1910)
Sup't Pavement Construction, Hastings Pavement Co.
Room 1827, 25 Broad St., N.Y. City

C., Charter Member.
L., Life Member.
(1908), Joined Association in 1908.

DROWN, Richard Wiggin, S.B. 1902 (1908)
Contracting Eng'r, Nichols & Drown Co.
17 Central Ave., Lynn, Mass.

DUDLEY, John C., S.B. 1904 (1909)
With Canadian Westinghouse Co.
65 Mansfield St., Montreal, P.Q., Can.

DUFFIELD, Morse Stewart, A.B. 1897 (1908)
Mining Eng'r 311 Dooly Block, Salt Lake City, Utah

DURFEE, Walter Chaloner, 2d, A.B. 1904; A.M. 1905 (L. 1908)
Experimental Eng'r, Walworth Mfg. Co.
40 Eliot St., Jamaica Plain, Mass.

DUTTON, Charles Henry, 1901 (C. 1908)
With J. R. Worcester & Co. Boston, Mass.
and 2 Wellington Ave., Waltham, Mass.

DUTTON, Francis Bird, A.B. 1897 (L. 1908)
Mech. Eng'r Lebanon, Pa.

EAMES, Horace Lovell, S.B. 1903 (1908)
District Eng'r, Bureau of Public Works Manila, P.I.

EATON, James Haworth, S.B. 1906 (C. 1908)
Civil Eng'r, with J. R. Worcester & Co. Boston, Mass.
and 1 Trowbridge Pl., Cambridge, Mass.

EATON, Joseph Jordan, S.B. 1896 (1908)
Director, Yonkers Trades School Yonkers, N.Y.

EDWARDS, Harold, A.B. 1896 (1908)
Elect. Eng'g 108 Mt. Vernon St., Boston, Mass.

ELLIOTT, Howard, C.E. 1881 (C. L. 1908)
President, Northern Pacific R. R.
208 Northern Pacific Bldg., St. Paul, Minn.

ELY, Frederick Burchard, S.B. 1904 (1909)
Ass't Eng'r, Arizona Copper Co. Morenci, Ariz.

EMERSON, K. B., A.B. 1902; A.M. 1904 (L. 1910)
Civil Eng'r 299 Broadway, N.Y. City

FAIRBANK, Wallace, A.B. 1895 (L. 1908)
Secy.-Treas., S. F. P. & P. Ry. Co. Prescott, Ariz.

FARLEY, Frank Cheney, A.B. 1902 (1908)
Architect South Manchester, Conn.

C., Charter Member.
L., Life Member.
(1908), Joined Association in 1908.

FEDELER, John H., 1897 (1910)
Sup't and Consulting Eng'r
N.Y. Produce Exchange Bldg., N.Y. City

FELTON, Edgar Conway, A.B. 1879 (C. L. 1908)
President, Pennsylvania Steel Co.
300 Franklin Bank Bldg., Phila., Pa.

FENNESSY, James Henry, Sp. 1893; LL.B. 1894 (L. 1908)
President, The Mine & Smelter Supply Co.
"Fenwood," Greenwich, Conn.

FINLAY, James Ralph, A.B. 1891 (C. 1908)
Gen'l Mgr., Goldfield Consolidated Mines Goldfield, Nev.

FISH, Walter Clark, 1886 (*M.I.T.*, S.B. 1887) (1908)
Manager General Electric Co., Lynn, Mass.

FISHER, Charles Heber, S.B. 1904 (L. 1908)
Elect. Eng'g 617 du Pont Bldg., Wilmington, Del.

FISHER, Richard Thornton, A.B. 1898 (*Yale*, M.F. 1903) (1909)
Ass't Prof. Forestry, H. U. 15 Ware Hall, Cambridge, Mass.

FITZPATRICK, Frank Richard, A.B. 1903 (1908)
Motive Power Inspector, Pennsylvania lines
406 E. Wayne St., Fort Wayne, Ind.

FLAGG, Josiah Foster, S.B. 1854 (1909)
Retired 2001 Anacapa St., Santa Barbara, Cal.

FLINN, Alfred Douglas (*W.I.P.*, S.B. 1893) Instr. Sanitary Eng'g, 1900-02, H.U. (1908)
Dept. Eng'r, B'd Water Supply N.Y. City
and Glenbrook Ave., Park Hill, Yonkers, N.Y.

FORTÉ, Harry Phidias, S.B. 1907; M.M.E. 1908 (C. 1908)
With Wm. Underwood Co. 52 Fulton St., Boston, Mass.

FOX, Henry Heywood, A.B. 1900; S.B. 1904 (1908)
Sup't Constr., Turner Constr. Co. 11 Broadway, N.Y. City
and 27 West 44th St., N.Y. City

FOX, John Pierce, A.B. 1894 (1908)
Transit Expert to Mayor Pittsburg, Pa.
and Chappaqua, Westchester County, N.Y.

FRANCIS, Richard Standish, S.B. 1902 (1908)
Bldg. Constr., Fuller Constr. Co. Fuller Bldg., N.Y. City

C., Charter Member.
L., Life Member.
(1908), Joined Association in 1908.

FROST, Vincent Morse, S.B. 1902 (1908)
With Westinghouse Machine Co. 165 Broadway, N.Y. City
and 22 Waverly St., Everett, Mass.

FROTHINGHAM, Francis Edward, A.B. 1894 (C. 1908)
219 Commonwealth Ave., Chestnut Hill, Mass.

FULLER, Edwin Sherman, S.B. 1908 (1909)
Jun. Eng'r, U. S. Geol. Surv. Box 972, Salt Lake City, Utah

FURNESS, Douglas Lyle, A.B. 1904; S.B. 1905 (L. 1908)
General Elect. Co., Boston Office 84 State St., Boston, Mass.
and 31 Warren St., Salem, Mass.

GARFIELD, Chester Arthur, S.B. 1904 (1910)
Ass't Eng'r, B'd of Water Supply N.Y. City
and P. O. Box 153, West Shokan, N.Y.

GERRISH, George Howard, S.B. 1901 (1908)
Architect and Eng'r, Warren & Gerrish
1107 Exchange Bldg., 53 State St., Boston, Mass.

GIBBS, George, Jr., S.B. 1904 (C. 1908)
Landscape Architect 15 Davis Ave., Brookline, Mass.

GIFFORD, Walter Sherman, A.B. 1905 (1908)
Ass't Sec'y and Ass't Treas., Western Electric Co.
377 Essex St., Salem, Mass.

GILMAN, Charles, S.B. 1904 (1908)
Ass't to Vice-Pres., Rodger Ballast Car Co. 90 West St., N.Y. City

GILMAN, Francis Lyman, A.B. 1895 (C. L. 1908)
Mo. & Kan. Tel. Co. Kansas City, Mo.

GOBLE, Frank N., *H.U. Grad. Sch.* 1903 (1908)
Contracting Eng'r 1 East 42d St., N.Y. City

GOLDMARK, Henry, A.B. 1878 (1908)
Designing Eng'r, Isthmian Canal Comm.
Culebra, Canal Zone, Panama
and 270 West 94th St., N.Y. City

GOODNOUGH, Xanthus Henry, A.B. 1882 (1908)
Chief Eng'r Mass. State Board of Health
and 70 Stratford St., West Roxbury, Mass.

GOULD, Chester M., S.B.1905 (1908)
Civil Eng'r Cold Spring-on-Hudson, N.Y.

C., Charter Member.
L., Life Member.
(1908) Joined Association in 1908.

Graupner, Marcellus F., 1903 (C. 1908)
Mining Los Angeles, Cal.
and 24 Bigelow St., Cambridge, Mass.

Greeley, Samuel A., A.B. 1903 (L. 1910)
Sanitary Eng'r City Hall, Milwaukee, Wis.

Green, Bernard Richardson, S.B. 1864 (L. 1908)
Civil Eng'r Library of Congress, Washington, D.C.

Greenlaw, Ralph Weller, S.B. 1902 (C. 1908)
Ass't Eng'r, B'd Water Supply, N.Y. Cold Spring, N.Y.

Hackett, Leon Abbott, S.B. 1904 (L. 1908)
Cotton Mfgr. Box 1866, Boston, Mass.

Hale, Herbert Miller, S.B. 1904 (C. 1908)
Ass't Eng'r, B'd Water Supply, N.Y. High Falls, N.Y.

Hall, George Duffield, A.B. 1899 (L. 1908)
Landscape Architect Dover, Mass.

Hammett, Philip Melancthon, A.B. 1888 (*M.I.T.*, S.B. 1890) (1908)
Sup't Motive Power, Maine Central R. R.
238 St. John St., Portland, Me.

Hanavan, William Laurence, A.B. 1903; S.B. 1904 (1909)
Civil Eng'r, B'd of Water Supply, N.Y.
R. F. D. No. 4, Newburg, N.Y.

Harrod, Benjamin Morgan, A.M. 1856 (*Tulane*, LL.D. 1906)
(C. 1908)
Consulting Eng'r 1637 Foucher St., New Orleans, La.

Hartwell, Oliver Whitcomb, A.B. 1908 (L. 1909)
Jun. Eng'r, U. S. Geol. Survey Box 972, Salt Lake City, Utah
and 77 Munroe St., Somerville, Mass.

Haskell, Adam Leopold, S.B. 1903 (1908)
Commercial Eng'r Care Nat'l Carbon Co., Cleveland, Ohio

Haskell, Augustus Story, A.B. 1887; C.E. 1888 (L. 1908)
2552A Gough St., San Francisco, Cal.

Hawks, Arthur Stearns, S.B. 1900 (1908)
Eng'r of Power Dept., Bethlehem Steel Co.
313 Wall St., Bethlehem, Pa.

Hayes, Lawrence Warner, S.B. 1907 (1908)
With Cornell Art Metal Co. Ilion, N.Y.

C., Charter Member.
L., Life Member.
(1908), Joined Association in 1908.

HEDRICK, William Archibald, S.B. 1905 (1908)
Eng'r and Capitalist 601 West 184th St., N.Y. City

HENDRICKS, Allan Barringer, Jr., Sp. 1901 (1908)
Elect. Eng'r 212 East St., Pittsfield, Mass.

HENRY, Lewis Warner, 1899 (1908)
Elect. Eng'r, Care of J. G. White Co., 43 Exchange Pl., N.Y. City

HERSCHEL, Clemens, S.B. 1860 (C. L. 1908)
Hydraulic Eng'r 2 Wall St., N.Y. City

HERSCHEL, Winslow Hobart, A.B. 1896 (C. L. 1908)
Care Clemens Herschel, 2 Wall St., N.Y. City

HILL, Samuel, A.B. 1879 (L. 1908)
Home Tel. Co. Portland, Ore.

HILLS, Leon Clark, 1902 (1908)
Sales Eng'r, Otis Elevator Co. 17 Battery Place, N.Y. City

HILLS, Oliver Soper, 1903 (1908)
Telephone Eng'r 106 Comstock Place, Syracuse, N.Y.

HITCHCOCK, Frank, 1885 (L. 1908)
Mfgr., Pig Iron 21 Central Sq., Youngstown, Ohio

HOGAN, John Philip, A.B. 1903; S.B. 1904 (1909)
Ass't Eng'r, B'd of Water Supply High Falls, N.Y.

HOLDEN, Albert Fairchild, A.B. 1888 (L. 1909)
"Plain Dealer" Cleveland, Ohio

HOLLIS, Ira Nelson, (Hon.) A.M. 1906 (*Union*, L.H.D. 1899)
(C. 1908)
Prof. Eng'g, H.U. 6 Acacia St., Cambridge, Mass.

HOLT, Arthur Clark, A.B. 1891 (L. 1908)
Contractor and Builder 202 Hancock Bldg., Boston, Mass.
and 197 Washington St., Somerville, Mass.

HOPKINS, Stephen Upshur, S.B. 1897 (C. 1908)
Eng'r, 6th Div., Public Service Comm. N.Y. City
and 23 Flatbush Ave., Brooklyn, N.Y.

HORNE, Harold Wellington, A.B. 1894; S.B. 1896 (L. 1908)
Ass't Eng'r, B'd Water Supply, N.Y. City
Cornwall-on-Hudson, N.Y.

HORNE, John Belton, A.B. 1904 (1908)
Telephone Eng'r Western Elect. Co., Hawthorne, Ill.

C., Charter Member.
L., Life Member.
(1908), Joined Association in 1908.

HOWARD, Philip Barthold, A.B. 1893 (1908)
Architect, Cummings & Howard 144 Congress St., Boston, Mass.

HUBBARD, Henry Vincent, A.B. 1897; A.M. 1899 (1908)
Instructor in Landscape Architecture, H. U., and Landscape Architect 56 Walter Hastings Hall, Cambridge, Mass.

HUDSON, Charles Henry, S.B. 1854 (1908)
Consulting Eng'r 1021 Circle Park, Knoxville, Tenn.

HUGHES, Harold Lincoln, S.B. 1900 (1908)
With U. S. Steel Products and Export Co.
Box 384, Sydney, N. S. W., Australia

HUGHES, Hector James, A.B. 1894; S.B. 1899 (C. 1908)
Ass't Prof. Civil Eng'g, H.U. 6 Clement Circle, Cambridge, Mass.

HUNT, William Prescott, Jr., 1881 (L. 1908)
Sec'y, The Buda Co. and Paige Iron Works
637 Railway Exchange, Chicago, Ill.

HUNTING, Eugene N., S.B. 1903 (1909)
Consulting Concrete Eng'r, Nicola Bldg. Co.
2115 Farmer's Bank Bldg., Pittsburg, Pa.

HUNTINGTON, Edward Vermilye, A.B. 1895; A.M. 1897 (C. 1908)
Ass't Prof. Mathematics, H.U. 27 Everett St., Cambridge, Mass.

HUNTINGTON, Dr. Oliver W., A.B. 1881; A.M., PH.D. (1910)
Head Master Cloyne House School, Newport, R.I.

HYDE, John Lawrence, 1894 (1908)
Ass't Town Eng'r 12 Pleasant St., Westfield, Mass.

IRVING, Gugy Æmilius, Jr., S.B. 1907 (1909)
Elect. Eng'r 102 Henderson Ave., New Brighton, N.Y.

IVY, Thomas Parker, A.B. 1881 (1908)
Forest Eng'r Conway Centre, N.H.

JACKSON, Arthur C., A.B. 1888 (1909)
Architect 23 Madison Square, North, N.Y. City

JACKSON, Herbert Arnold, S.B. 1903 (1908)
N. E. Sales Agent, Bethlehem Steel Co.
165 High St., Boston, Mass.

JAMES, Gorton, A.B. 1908 (1909)
Student at M.I.T. 33 Buckminster Rd., Brookline, Mass.

JENNINGS, Hennen, C.E. 1877 (L. 1909)
Mining Eng'r 2221 Massachusetts Ave., Washington, D.C.

C., Charter Member.
L., Life Member.
(1908), Joined Association in 1908.

JENNINGS, Sidney J., C.E. 1885 (L. 1908)
Mining Eng'r Park Cottage, Dobbs Ferry, N.Y.

JOHNSON, Arthur N., S.B. 1894 (1910)
State Highway Eng'r State Highway Comm., Springfield, Ill.

JOHNSON, Lewis Jerome, A.B. 1887; C.E. 1888 (C. L. 1908)
Prof. Civil Eng'g, H.U. 90 Raymond St., Cambridge, Mass.

JONES, Frank Lorimer, S.B. 1902 (1909)
Ass't Eng'r with N.Y. B'd of Water Supply
Yorktown Hts., Westchester County, N.Y.

JONES, Frederic Marshall, A.B. 1896; S.B. 1900 (C. 1908)
Architect 919 Exchange Bldg., Boston, Mass.

KENNEDY, Frank Lowell, A.B. 1892; S.B. 1898 (C. L. 1908)
Ass't Prof. Drawing & Machine Design, H.U.
43 Appleton St., Cambridge, Mass.

KENNELLY, Arthur Edwin, (Hon.) A.M. 1906 (*Western Univ. of Pa.*, (Hon.) D.SC. 1895) (C. L. 1908)
Prof. Elect. Eng'g, H.U. 1 Kennedy Rd., Cambridge, Mass.

KILLAM, Charles Wilson, Sp. 1907 (C. 1908)
Ass't Prof. Arch. Construction, H.U.
20 Walker St., Cambridge, Mass.

KLEIN, Samuel Mark, S.B. 1901 (1909)
Civil Eng'r 2923 West North Ave., Baltimore, Md.

KLINE, Robert Everett, S.B. 1893 (L. 1908)
R'y. Sanitary, Municipal Eng'g 545 Superior Ave., Dayton, O.

KNOBLAUCH, George W., A.B. 1897 (L. 1909)
Mining Eng'r 27 West 44th St., N.Y. City

LADD, George Edgar, A.B. 1887; A.M. 1888; PH.D. 1894 (1908)
Pres., Oklahoma School of Mines and Metallurgy
Wilburton, Okla.

LECLEAR, Gifford, A.B. 1895; A.M. 1896 (L. 1908)
Consulting Eng'r and Mill Architect, Densmore & LeClear
88 Broad St., Boston, Mass.

LEITER, Joseph, A.B. 1891 (1908)
Coal Operator 48 Van Buren St., Chicago, Ill.

LEMONT, Frank Harold, A.B. 1903; A.M. 1904 (1909)
With Western Elect. Co. Box 452, Riverside, Ill.

LESTER, Daniel H., S.B. 1904 (1908)
Fire Ins. Eng'g 29 West 91st St., N.Y. City

C., Charter Member.
L., Life Member.
(1908), Joined Association in 1908.

LEVINE, Joseph M., 1906 (1908)
Ass't Eng'r, B'd of Water Supply 127 Franklin St., N.Y. City

LEWIS, Frederick C., S.B. 1897 (L. 1908)
Mining Gallipolis Ferry, W. Va.

LIBBEY, Joseph Harold, S.B. 1898 (C. L. 1908)
Mech. & Elect. Eng'r 147 Milk St., Boston, Mass.
and 14 Parsons St., West Newton, Mass.

LIBBEY, Miles Augustus, 1906 (1909)
Ensign, U. S. Navy Care of Navy Dept., Washington, D.C.

LINCOLN, Edward Lewis, A.B. 1908; S.B. 1909 (1910)
Civil Eng'r Y. M. C. A., White Plains, N.Y.
and 27 Cedar Rd., Belmont, Mass.

LINCOLN, Henry Lewis, A.B. 1906; S.B. 1907 (C. 1908)
Power & Mining Dept., General Elect. Co.
33 Front St., Schenectady, N.Y.

LINZEE, John William, A.B. 1890 (*M.I.T.*, S.B. 1889) (C. L. 1908)
96 Charles St., Boston, Mass.

LIVERMORE, Joseph Perkins, A.B. 1875; C.E. 1877 (L. 1908)
Mech. Expert (Witness in Patent Cases)
59 Brewster St., Cambridge, Mass.

LIVERMORE, Robert, A.B. 1900 (*M.I.T.*, S.B. 1903) (1908)
Mining Eng'r
Care Lindsley, Townsend & Livermore, Telluride, Col.

LOMAX, Harold A., 1903 (1908)
Travelling Salesman, Mill Machinery Box 212, Oakmont, Pa.

LOVE, James Lee, A.M. 1890 (*Univ. of N. C.*, PH.B. 1884) (1908)
Ass't Prof. Math., H.U. 16 Francis Ave., Cambridge, Mass.

LOWELL, James Duane, A.B. 1874; C.E. 1877 (1908)
Civil Eng'r Corvallis, Oregon

LUCK, Charles W., A.B. 1889 (1908)
Civil Eng'r Weiser, Idaho

LUPIEN, Ulysses John, S.B. 1906 (1909)
Instr. Elect. Eng'g, Lowell Textile School Lowell, Mass.

LYMAN, Frank, A.B. 1874 (L. 1908)
Treasurer 88 Wall St., N.Y. City

MACARTHUR, Arthur Fred, A.B. 1882 (L. 1909)
Pres., MacArthur Bros. Co., Eng'rs & Contractors
11 Pine St., N.Y. City

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MacArthur, John R., A.B. 1885 (L. 1909)
Contractor 11 Pine St., N.Y. City

Mandigo, Clark Rogers, A.B. 1906; M.C.E. 1907 (1908)
Civil Eng'r and Sup't of Construction for War Dept., U. S. A.
Fort Riley, Kan.

Manierre, George, A.B. 1900 (*Armour Inst.*, M.E. 1904) (1908)
Eng'r 163 Martin St., Milwaukee, Wis.

Mann, Albert, A.B. 1895 (L. 1909)
With John A. Roebling Sons' Co.
45 Sewall St., West Newton, Mass.

Manning, Charles Henry, S.B. 1862 (1908)
Mech. Eng'r (Chief Eng'r, U.S.N., Retired)
Amoskeag Mfg. Co., Manchester, N.H.

Marean, Parker Endicott, A.B. 1903; S.B. 1905 (1909)
Sup't, B. & R. Rubber Co. No. Brookfield, Mass.

Marks, Lionel Simeon (*London Univ.*, S.B. 1892) (*Cornell*, M.M.E. 1894) (C. L. 1908)
Ass't Prof. Mech. Eng'g, H.U.
88 Lake View Ave., Cambridge, Mass.

Martin, Wisner, S.B. 1890 (1908)
Architect and Eng'r 50 Highland Ave., Cambridge, Mass.

Mason, Francis, A.B. 1896 (C. 1908)
Civil Eng'r 99 Rockview Ave., Plainfield, N.J.

Massa, Robert Falconer, S.B. 1898 (1910)
Salesman Creamery Package Mfg. Co., Albany, N.Y.

McDewell, Horatio Sprague, S.B. 1907; M.M.E. 1908 (C. 1908)
Student Apprentice 478 64th Ave., West Allis, Wis.

McEnteer, Frank Duff, A.B. 1905 (C. 1908)
Ass't Consulting Eng'r 704 Empire Bldg., Pittsburg, Pa.

McIntosh, Frederick Fleming, S.B. 1903; MET.E. 1905 (1908)
Instr. in Metallurgy, Carnegie Tech. Schools Pittsburg, Pa.

McKay, George Albert, A.B. 1908 (1909)
With Foundation Co., Brownsville Bridge Brownsville, Tex.

Meadowcroft, William, S.B. 1901 (1908)
Ass't Eng'r (Designer), B'd Water Supply
299 Broadway, N.Y. City

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MENDENHALL, Walter Curran, 1897 (*Ohio State Normal*, S.B. 1891) (L. 1908)
Geologist U. S. Geol. Survey, Washington, D.C.

MERIAM, Welles, A.B. 1899 (L. 1909)
Ass't Examiner, U.S. Patent Office Washington, D.C.

MEYER, Albert R., Sp. 1899 (C. 1908)
Electrician, Mining Eng'r, Stenographer
156 Ivy St., Brookline, Mass.

MILINOWSKI, Arthur Siegfried, S.B. 1904 (1908)
Ass't Eng'r, Barge Canal Winslow Block, Brockport, N.Y.

MILLER, Sidney W., 1885 (L. 1908)
Mfgr. "Miller" Automatic Siphons 184 La Salle St., Chicago, Ill.

MILLS, Charles Wilson, S.B. 1895 (C. 1908)
Elect. Eng'r and Contracting 1444 Mass. Ave., Cambridge, Mass.

MONKS, Archibald G., S.B. 1904 (1910)
Structural Eng'r, Monks & Johnson 7 Water St., Boston, Mass.

MONTAGUE, Samuel Skerry, S.B. 1897 (L. 1909)
Pres., St. Helens Quarry Co.; Vice-Pres., Montague-O'Reilly Co.,
Gen'l Contractors 1 Front St., Portland, Ore.

MORRILL, Charles Henry, S.B. 1900; A.B. 1901 (1908)
Insurance and Fire Protection 1226 Pierce Bldg., St. Louis, Mo.

MORSE, Philip Sidney, A.B. 1881 (*M.I.T.*, S.B. 1884) (1909)
Mgr., Sulphide Corp. Ltd. Cockle Creek, New So. Wales

MOSES, Ernest Maebry, S.B. 1897 (L. 1908)
Draftsman Boston Elevated Ry., Boston, Mass.
and Worcester Lane, Waltham, Mass.

MOSES, Edmund Quincy, S.B. 1902 (1908)
Patent Lawyer 1 Liberty St., N.Y. City

MOSES, Percy Lawrence, S.B. 1906 (1908)
Edison Elect. Ill. Co. Boston, Mass.
and 747 Washington St., Brookline, Mass.

MOWLL, William Luther, S.B. 1899 (C. 1908)
Ass't Prof. Architecture, H.U. 40 Avon Hill St., Cambridge, Mass.

MOYER, James Ambrose, S.B. 1899; A.M. 1904 (C. L. 1908)
Ass't Prof. Mech. Eng'g, Univ. Mich. Ann Arbor, Mich.

MULLGARDT, Louis C., 1893 (L. 1909)
Architect Chronicle Bldg., San Francisco, Cal.

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NEALE, Laurance Irving, A.B. 1906 (1908)
Cement Mfgr. Care J. B. King & Co., 17 State St., N.Y. City

NEFF, Nettelton, A.B. 1892 (L. 1908)
Division Sup't, Richmond Div.
Care Pennsylvania Lines, Richmond, Ind.

NELSON, Fred A., 1904 (1909)
With Westinghouse, Church, Kerr & Co.
22 West 60th St., N.Y. City

NEWELL, George Russell, S.B. 1905 (1908)
Civil Eng'r, Matthews & Newell
Room 6, Maccabee Bldg., Rochester, N.Y.

NICHOLS, John R., A.B. 1906 (L. 1908)
Instr. in Civil Eng'g, H.U. 82 Avon Hill St., Cambridge, Mass.

NOURSE, Franklin, A.B. 1870 (L. 1908)
Manufacturer Lawrence Mfg. Co., Lowell, Mass.

OLDS, Norman Evry, S.B. 1905 (L. 1908)
Westinghouse Elect. & Mfg. Co. 418 Main St., Dallas, Texas.

OLMSTED, Frederick Law, A.B. 1894 (1908)
Landscape Architect Brookline, Mass.

OLSSON, Frederick Arthur, S.B. 1892 (1908)
Art Dealer & Publisher 9 Boylston St., Cambridge, Mass.

OSBORN, John Frederick, A.B. 1896 (L. 1908)
Mill Eng'g Care C. T. Main, 45 Milk St., Boston, Mass.
and 314 Harvard St., Cambridge, Mass.

OSBORNE, Charles, A.B. 1900 (L. 1908)
Civil Engineer North Weare, N.H.

PARTRIDGE, Warren, S.B. 1897 (1909)
Gen'l Sup't., Springfield Ry. & St. Cos. Springfield, Ill.

PATTEN, William Samuel, A.B. 1895 (L. 1908)
Treas., Holbrook, Cabot & Rollins Corp.
6 Beacon St., Boston, Mass.

PATTERSON, Andrew Henry, A.B. 1892; A.M. 1893 (1908)
Prof. Physics, Univ. of N.C. Chapel Hill, N.C.

PATTERSON, Harold Truesdel, B.A.S. 1902 (1909)
Landscape Architect Westbury, Long Island, N.Y.

PATTERSON, James George, A.B. 1903 (C. 1908)
Eng'g Dept., N. E. Tel. & Tel. Co. 164 High St., Boston, Mass.

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PATTERSON, Philip Merrill, S.B. 1905 (C. 1908)
Salesman, Westinghouse Elect. & Mfg. Co.
28 Hillside Ave., Arlington Hts., Mass.

PEARSE, Langdon, A.B. 1899 (*M.I.T.*, S.B. 1901; S.M. 1902) (1908)
Ass't Eng'r in charge Sewage Disposal Investigations, Sanitary District of Chicago 1500 Am. Trust Bldg., Chicago, Ill.

PENROSE, Richard Alexander Fullerton, Jr., A.B. 1884;
A.M., PH.D. 1886 (1908)
460 Bullitt Bldg., Philadelphia, Pa.

PENROSE, Spencer, A.B. 1886 (L. 1908)
Mining & Metallurgy Colorado Springs, Col.

PERIN, Charles Page, A.B. 1883 (1909)
Consulting Eng'r 2 Rector St., N.Y. City

PERKINS, Albert Thompson, A.B. 1887 (L. 1908)
Pres., Chicago, Milwaukee & Gary Ry.; Pres., Marshall & East Texas Ry.; Pres., New Iberia & Northern Ry.; 1st Vice-Pres., St. Louis, Brownsville, & Mexico Ry.
401 Locust St., St. Louis, Mo.

PERRY, Chauncy Rusch, S.B. 1895 (C. 1908)
Ass't Eng'r, Boston Transit Comm.
Greenwood Ave., Waltham, Mass.

PERRY, John Prince Hazen, S.B. 1903 (1909)
Mgr., Contract Dept., Turner Construction Co. N.Y. City
and Harvard Club, N.Y. City

PETERS, Edward Dyer, M.D. 1877 (L. 1910)
Mining Eng'r and Prof. of Metallurgy, H. U.
38 Percival St., Dorchester, Mass.

PETTEBONE, Lauren A., S.B. 1905 (1908)
Construction Eng'r 307 Buffalo Ave., Niagara Falls, N.Y.

PIPER, William Bridge, A.B. 1903 (1908)
Forestry Forest Service, Missoula, Mont.

PLEASONTON, Frank Rodney, S.B. 1906; M.M.E. 1908 (C. L. 1908)
166 W. Horrter St., Germantown, Pa.

POPE, Chester Couch, A.B. 1908; M.E.E. 1909 (1909)
With Stone & Webster Co. Key West, Fla.

POPE, Frederick, S.B. 1901 (1908)
Vice-Pres. & Chief Eng'r, Southern Mfg. Co.
27 West 44th St., N.Y. City

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Associate Editor "The Motor World"
P. O. Box 649, N.Y. City

QUACKENBUSH, Harry Sargent, S.B. 1906 (1908)
Elect. Eng'r Box 255, Schenectady, N.Y.

QUINLAN, John Vincent, S.B. 1907 (1908)
With Edwin C. Lewis, Elect. Eng'rs Boston, Mass.
and 52 High St., Brookline, Mass.

RAYMER, George Sharp, A.B. 1878 (*Columbia*, E.M. 1881) (1910)
Asst. Prof. of Mining, H. U. 51 Brattle St., Cambridge, Mass.

REED, William Maxwell, 1893 (1908)
Mgr. Premium & Cost Depts. of B. T. Babbitt
82 Washington St., N.Y. City

REMINGTON, Franklin, A.B. 1887 (C. 1908)
Contractor The Foundation Co., 115 Broadway, N.Y. City

RICE, Claude Thayer, A.B. 1901; S.B. 1903 (1909)
Mining Dillard, Douglas County, Oregon

RICE, George Staples, S.B. 1870 (C. 1908)
Eng'r, Subway Construction, Public Service Comm., N.Y. City
154 Nassau St., N.Y. City

RICHARDS, Gragg, S.B. 1902; S.M. 1903 (L. 1909)
Mining and Civil Eng'r 135 Court St., Dedham, Mass.

RIDGEWAY, Robert (Hon. 1909)
Dept. Eng'r, N.Y. B'd of Water Supply
236 Main St., Poughkeepsie, N.Y.

RIGGS, Francis Behn, A.B. 1903 (1909)
Marine Eng'r, Alaska S. S. Co.
2425 Westview Drive, Seattle, Wash.

ROGERS, Mason Thatcher, A.B. 1908; M.C.E. 1909 (L. 1909)
Ass't Eng'r with A. T. Safford Lowell, Mass.
and 63 Fifth Ave., N.Y. City

ROSS, Louis, A.B. 1904; S.B. 1905 (1908)
U. S. Deputy Surveyor 244 Kearney St., San Francisco, Cal.

RUMERY, Ralph R., 1899 (1909)
Chief Eng'r, N.Y. State B'd of Tax Comm.
The Capitol, Albany, N.Y.

RYAN, Michael Healey, S.B. 1899 (1909)
Ass't Eng'r, Pub. Serv. Comm. 154 Nassau St., N.Y. City

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Prof. of Physics and Dean Grad. Sch. App. Sc., H.U.
16 University Hall, Cambridge, Mass.

SANBORN, James Forrest, S.M. 1899 (1908)
Div. Eng'r, B'd Water Supply, N.Y. City Peekskill, N.Y.

SARGEANT, Charles Asa, A.B. 1906; S.B. 1907 (1909)
B'd of Water Supply Maple Creek, Saskatchewa, Can.

SAVAGE, George Hubbard, A.B. 1891 (L. 1908)
Factory Chemist 180 Lincoln St., Worcester, Mass.

SAVILLE, Caleb Mills, A.B. 1889 (1910)
Civil Eng'r in charge 3d Div. Isth. Can. Comm.
Culebra, Canal Zone, Panama

SAWYER, Harris E., A.B. 1891; PH.D. 1895 (1909)
Chemical Eng'r, U. S. Dept. Agriculture
Bureau Chemistry, Washington, D.C.

SEAVER, Clifford, S.B. 1903 (1909)
Civil Eng'r 262 Franklin St., Cambridge, Mass.

SHAUGHNESSY, Charles Stephen, S.B. 1901 (1908)
Civil Eng'r Cold Spring-on-Hudson, N.Y.

SHERBURNE, Kenneth, S.B. 1903 (L. 1908)
Ass't Eng'r, Sturtevant Mill Co. Harrison Sq., Boston, Mass.
and 363 Marlboro St., Boston, Mass.

SHERTZER, Tyrrell Bradbury, S.B. 1900 (C. 1908)
Ass't Eng'r, Pub. Serv. Comm. (First District)
154 Nassau St., N.Y. City
and 25 West Preston St., Baltimore, Md.

SICKLES, Raymond, S.B. 1907 (1908)
Civil Eng'r 122 West Ave., Lockport, N.Y.

SILVERMAN, Nathaniel Lawrence, A.B. 1903 (1909)
Office Manager, Silverman Eng'g Co.
27 School St., Boston, Mass.

SILVERMAN, Peyser Edward, 1904 (1909)
Civil Eng'r, Silverman Eng'g Co. 27 School St., Boston, Mass.

SIMPSON, Tennyson Wendell, A.B. 1905; S.B. 1906 (1909)
Elect. Eng'r 38 Laurel St., Whitman, Mass.

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SLOCUM, Curlys Lyon, 1909 (1908)
Ass't Eng'r, N. Y., N. H., & H. R. R.
314 R. R. Bldg., New Haven, Conn.

SMITH, Allen, S.B. 1905 (1909)
Ass't Eng'r, B'd Water Supply Olive Bridge, Ulster Co., N.Y.

SMITH, Harrison Willard, A.B. 1895 (1908)
Assoc. Prof. of Elect. Eng'g, Mass. Inst. of Technology
Boston, Mass.

SMITH, Lyon, S.B. 1905 (1910)
Mining Eng'r Care of Cortez Metals Recovery Co.
Cortez, Lander Co., Nev.

SMYTH, Henry Lloyd, A.B. 1883; C.E. 1885 (1910)
Prof. Mining & Metallurgy, H.U. Rotch Bldg., Cambridge, Mass.

SOUTHER, Allan Bartlett, S.B. 1897 (1908)
Scrap Dealer and Teacher, Baltimore Polytechnic Inst.
1211 W. Mulberry St., Baltimore, Md.

SOUTHER, Dana Wheelock, 1905 (1909)
Eng'r in charge of construction, Russell Falls Paper Co.
Russell, Mass.

SPALDING, Philip Leffingwell, A.B. 1892; A.M. 1893; S.B. 1894
(L. 1908)
Gen'l Mgr., Bell Tel. Co. of Pennsylvania
345 South 18th St., Philadelphia, Pa.

SPURR, Josiah Edward, A.B. 1893; A.M. 1894 (L. 1908)
Mining Geologist & Eng'r 165 Broadway, N.Y. City

ST. GEORGE, William, 1907 (1909)
With M. B. Foster Elect. Co. 436 Main St., Waltham, Mass.

STARK, Charles Wolcott, S.B. 1903 (1908)
Ass't Eng'r, N.Y. C. & H. R. R. R.
65 So. Oxford St., Brooklyn, N.Y.

STEARNS, George Hermon, A.B. 1878 (C. 1908)
Ass't Eng'r, Boston Transit Comm. 15 Beacon St., Boston, Mass.

STEEDMAN, George Fox, A.B. 1892 (C. L. 1908)
Care Curtis & Co. Mfg. Co., St. Louis, Mo.

STEINMETZ, Charles Proteus, (Hon.) A.M. 1902 (L. 1908)
Consulting Eng'r, Gen'l Elect. Co.; Prof. Elect. Eng'g, Union Univ. Wendell Ave., Schenectady, N.Y.

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STETSON, Henry Niebuhr, S.B. 1903 (L. 1909)
Mgr., St. John Pulp & Paper Co. St. John, N.B.

STURGIS, Arthur, S.B. 1900 (1908)
With John H. Bickford, Engineers
79 Cypress St., Brookline, Mass.

SULLIVAN, Richard Thomas, S.B. 1906 (1909)
With Houston Electric Co. Houston, Texas

SWAIN, George Fillmore (*M.I.T.*, S.B. 1877; *N.Y.U.*, LL.D. 1907) (L. 1909)
Prof. Civil Eng'g, H.U. 435 Marlboro St., Boston, Mass.

SWIFT, John F., 1903, 1904 (L. 1908)
Foreman, Elect. Div., Pub. Bldgs. Dept. Boston, Mass.
and 48 Elmwood St., Roxbury, Mass.

TAYLOR, Edward Randolph, S.B. 1868 (1908)
Mfg. Chemist Penn Yan, N.Y.

TAYLOR, Frederick W. (*Stevens Inst.*, M.E. 1883) (1908)
Consulting Eng'r
Highland Station, Chestnut Hill, Philadelphia, Pa.

TERBUSH, Myron Emmet, S.B. 1900 (1909)
New Business Mgr., Topeka Edison Co. Topeka, Kan.

THAYER, Benjamin Bowditch, C.E. 1885 (C. L. 1908)
Pres., Anaconda Copper Mining Co. 42 Broadway, N.Y. City

THOMSON, Robert Douglas, S.B. 1907 (C. L. 1908)
72 Buell St., Burlington, Vt.

THORNDIKE, Sturgis Hooper, A.B. 1890 (*M.I.T.*, S.B. 1895) (L. 1908)
Ass't Eng'r, Eng'g Dep't 60 City Hall, Boston, Mass.

TILDEN, Charles Joseph, S.B. 1896 (1908)
Junior Prof. of Civil Eng'g, Univ. of Michigan Ann Arbor, Mich.

TIRRELL, Charles Edwards, S.B. 1904 (1908)
Ass't Eng'r, Turner Construction Co. 11 Broadway, N.Y. City
and 154 Wallace Ave., Mt. Vernon, N.Y.

TRAIN, Arthur Herman, S.B. 1905 (C. 1908)
With N.Y. Central R. R. 145 Forest St., Medford, Mass.

TUCKER, Herman Franklin, S.B. 1901 (L. 1908)
Designing Eng'r, Dept. of Constr. & Eng'g, Isth. Can. Comm.
Culebra, Canal Zone, Panama

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TURNER, Howard Moore, A.B. 1906; S.B. 1907 (1909)
With Turner Construction Co. Harvard Club, N.Y. City

UPDEGRAFF, William Barrett, 1902–1903, 1903–1904 (1910)
Mech. Eng'r 209 Dyckman St., N.Y. City

VAUGHAN, Frank Apthorp, A.B. 1898; S.B. 1900 (1909)
Ass't Sup't, National Carbon Co. Cleveland, Ohio

VAUGHAN, John Fairfield, S.B. 1895 (C. L. 1908)
Eng'r, Stone & Webster Eng'g Corp. 147 Milk St., Boston, Mass.

WADSWORTH, Lewis Lumber, S.B. 1903 (1908)
Eng'r & Contractor 53 State St., Boston, Mass.

WAIT, John Cassan, Instr. and Ass't Prof., H.U., 1887–1894 (L. 1908)
Atty. at Law, Eng'g Jurisprudence 38 Park Row, N.Y. City

WAITT, Walter Gustavus, A.B. 1900 (1908)
Ass't Sup't, National Carbon Co.
315 So. Washington St., Fremont, Ohio

WALTERS, Henry, 1873 (L. 1908)
Chairman, B'd Atlantic Coast Line and Louisville & Nashville R.R.
29 Abell Bldg., Baltimore, Md.

WARE, John, S.B. 1899 (1908)
Ass't Eng'r, Boston El. Ry. 18 Ash St., Cambridge, Mass.

WATSON, William, S.B. 1857 (Eng'g); S.B. 1858 (Math.) (1908)
Prof. of Eng'g, Retired (Sec'y Am. Acad. A. & S., Boston)
107 Marlboro St., Boston, Mass.

WEBSTER, Lawrence Burns, S.B. 1906 (1908)
Sup't, Bliss & Laughin, Inc. Harvey, Ill.
and 926 South Washington St., Marion, Ind.

WELD, Christopher Minot, A.B. 1897; S.M. 1901 (1908)
Mining Eng'r 2 Rector St., N.Y. City

WHEELER, Homer Charles, S.B. 1902 (1908)
6321 Ruby St., Los Angeles, Cal.

WHITE, Otis Converse, Jr., S.B. 1896 (L. 1908)
Mfgr. 8 Shepard St., Worcester, Mass.

WHITING, Edward Clark, A.B. 1903 (1908)
Landscape Architect 4 Avon St., Cambridge, Mass.

WHITING, Stephen Edgar, S.B. 1896 (C. L. 1908)
Boston Elevated Ry. Co. 11 Ware St., Cambridge, Mass.

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WHITNEY, George Brackett, S.B. 1899 (1908)
Steam & Mech. Eng'g 75 Puritan Rd., Swampscott, Mass.

WHITTIER, Edward J., M.E. 1901 (1910)
Mech. Eng'r Roselle, N.J.

WILLARD, Norman Rand, A.B. 1900 (C. L. 1908)
2277 Mass. Ave., No. Cambridge, Mass.

WILLIS, E. Newton, S.B. 1903 (1909)
With Gen'l Elect. Co. 12 Gillespie St., Schenectady, N.Y.

WILSON, James A., S.B. 1903 (1910)
Ass't Eng'r, Rapid Transit Subway Constr. Co.
Room 4, 200 Joralemon St., Brooklyn, N.Y.
and Bernardsville, N. J.

WISEMAN, John M., Sp. 1908 (C. 1908)
Plasterer 4 Gore St., Cambridge, Mass.

WITHINGTON, Sidney, A.B. 1906; S.B. 1907 (1908)
With Walworth Mfg. Co. Boston, Mass.
and 35 Bay State Rd., Boston, Mass.

WONSON, S. L., A.B. 1899 (1910)
Civil Eng'r Care Mexican Ry., Mexico City

WOODWORTH, Jay Backus, S.B. 1894 (1908)
Ass't Prof. of Geology, H.U.
Geological Museum, Cambridge, Mass.

WORCESTER, Joseph Ruggles, A.B. 1882 (C. L. 1908)
Consulting Civil Eng'r 79 Milk St., Boston, Mass.

WRIGHT, David Clarence, S.B. 1904 (1908)
Chief Draftsman with Electric Controller and Mfg. Co.
Cleveland, Ohio

WRIGHT, James Hayden, A.B. 1892 (1909)
Architect 371 Harvard St., Cambridge, Mass.

WRIGHT, Reuben I., 1899 (1909)
Engineer, Electric Controller & Mfg. Co. Cleveland, Ohio

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ENGINEERING AND ARCHITECTURE
AT HARVARD UNIVERSITY

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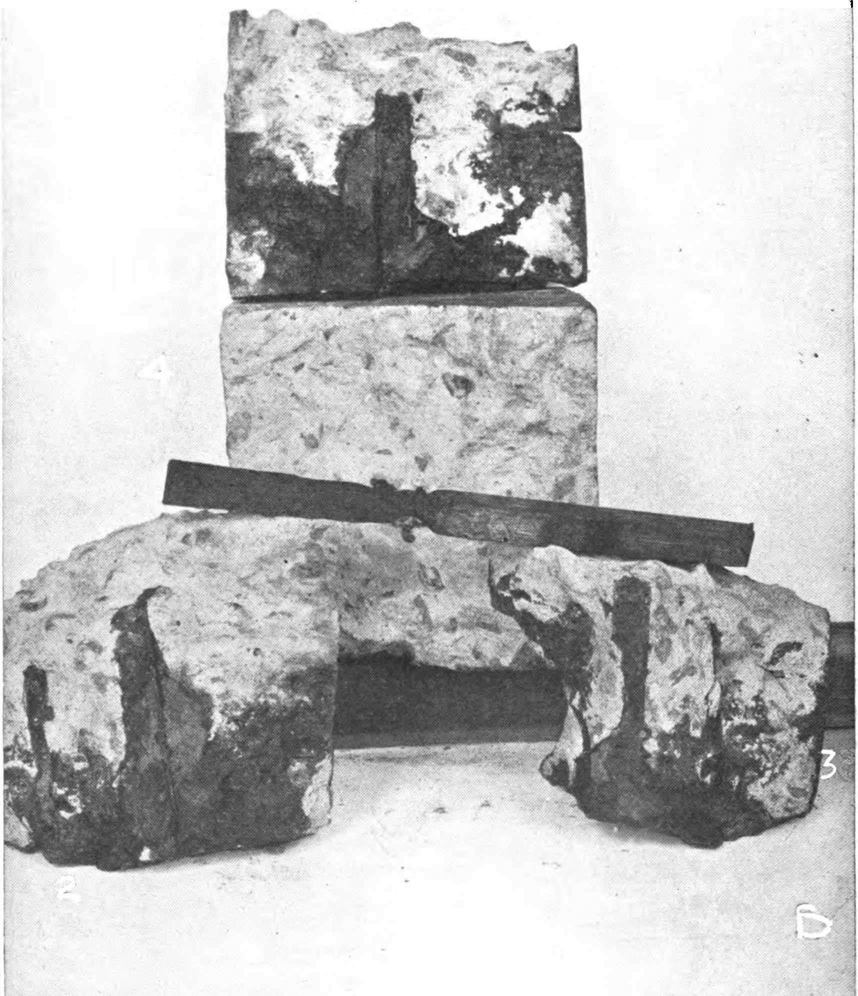

Frontispiece. *See page 135.* Fig. 3.

INTERIOR OF BLOCK No. 3.

HARVARD ENGINEERING JOURNAL

A QUARTERLY

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VOL. IX NOVEMBER, 1910 NO. 3

AN INVESTIGATION OF THE CORROSION OF IRON IMBEDDED IN CONCRETE

A STUDY OF THE ACTION OF STRAY CURRENTS

BY GUY F. SHAFFER

The development of the modern science of building construction and bridge work and the economic needs of the larger cities have slowly outlined the limitations of most of the structural materials, and have brought into great prominence the use of iron in alloys and combinations. Of the former standard materials, stone, brick or burned products, and wood, we know with a fair amount of certainty, under what conditions they can be used practically and how long they will be structurally safe. Of iron, a material in which every architect, engineer and builder is placing more faith than in any other part of the structure, we know very little; or at least totally ignore for the present the one certain fact that is everywhere evident, namely, that iron decays more rapidly than any other material in building construction. All of our theories of the present use of iron are based on its first strength under ideal conditions rather than its action in use. This carelessness and lack of foresight in design is echoed in erection and fostered in maintenance. With all of our many years of the "Iron Age" it is only within the age of a high school boy that any attention has been given to a careful study of iron, its manufacture, its uses, its deterioration, and its limitations.

Tremendous strides are now being made to find out the reasons for decay, although the cry of everyone who uses this

material is not, "Why does it decay?" but "How can decay be prevented with our present knowledge of preservation?" The question of "how" seems to include "why," or vice versa, and "why" appears to offer the better line of attack.

A recent publication of Messrs. Cushman and Gardner* gives in a concise form a compilation of the most recent investigations on the subject of corrosion and covers the ground more thoroughly than was possible in the scope of this investigation

The work undertaken by the writer was a study of conditions under which iron might decay more rapidly than under atmospheric exposure and, if the results warranted further investigation, to put them before men of an investigative turn of mind for further study and research along well-defined lines, in order that conditions of study might be comparative and the results of value to engineering science.

At the outset it must be thoroughly understood that these results are distinctly not scare-heads for newspaper articles, to be read and misunderstood by laymen, but are based on theoretical cases only, in which we may or may not have parallel examples in practice. The theory is as yet too crude for general understanding; the field of investigation has not been extended to practical observation, and the results will not be in shape for practical use until a long series of similar tests is made and checked.

Where iron in use is exposed to the atmosphere, we can study, with comparative ease, how well it is protected; but when once it is encased by brick, stone, or concrete we cease to worry. Generally speaking, there is little cause for disquietude, but it is the specific cases which need careful study and investigation. Steel or iron well imbedded in lime mortar and covered with stone or brick seems immune from excessive ordinary corrosion, and concrete appears to be even better as protection. Long time tests have not disturbed this theory. The slight porosity of the protecting coat in either case does not seem to materially affect the iron. But the increasing use of electricity introduces a factor that calls for careful and serious investigation. The best solution of the problem of ordinary corrosion is answered by the electrolytic theory. Electrolytic corrosion due to a current from

* "The Corrosion and Preservation of Iron and Steel," by Allerton S. Cushman and Henry A. Gardner, McGraw-Hill Book Company, New York, 1910.

an outside source is but an aggravated case of ordinary corrosion. Imbedding the iron seems to prevent ordinary corrosion, but does it eliminate or minimize the effect of stray currents?

The first investigation of this question was a series of experiments carried on by Mr. Maximilian Toch (Vol. 6, Pro. Amer. Soc. Testing Mat., 1906). The only problem he attempted to solve was "At which of the poles corrosion occurs." We now know definitely that corrosion occurs only at the anode, that is, where the current leaves the iron. Mr. Toch's tests are

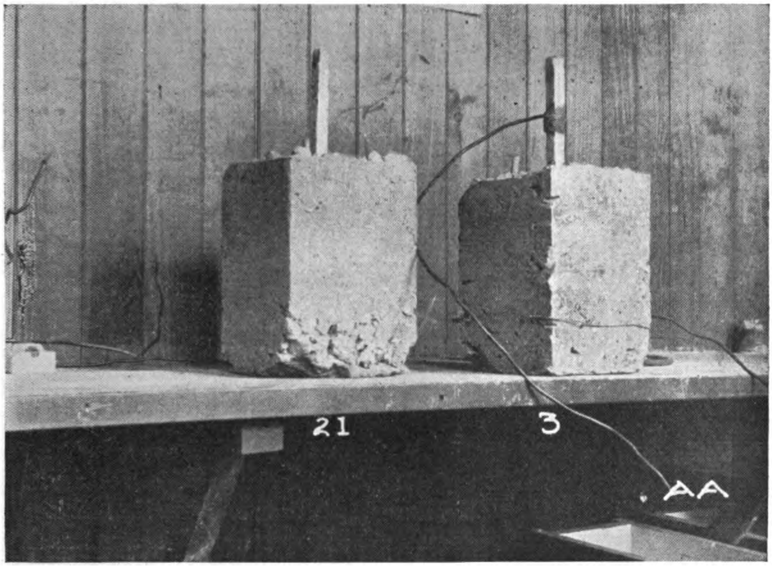


FIG. 1.
VIEW OF PRELIMINARY TEST BLOCKS.

interesting but not valuable, as no definite data beyond that one fact are given.

The next series of tests was carried on by Mr. Knudson. (See Vol. XXIV, Trans. Amer. Inst. E. E.) His tests showed that neat cement three inches thick will not protect pipes from corrosion with a constant current of 0.1 amperes.

Mr. Nicholas, Mass. Inst. Technology '08, duplicated Mr. Knudson's tests with practically the same results.

In 1908, Mr. Glauber, a senior in the electrical department at Washington University, duplicated Mr. Knudson's tests, using 1:3:5 concrete.

In 1909, Mr. Eltinge, a senior in the electrical department of Rennsalaer Polytechnic Institute, carried on a series of experiments which, while interesting, are not of a practical value as the voltage was too high for practical tests.

The general result of these experiments was to show that current from an outside source on leaving unstressed, unpainted iron, such as is used in iron pipes, will not only cause corrosion of the iron but will split the concrete.

The practical questions which naturally arise are:—

(1) What is necessary in the chemical composition of the steel in order that corrosion may be a minimum?

We see iron of different grades in every conceivable form corroding without any attention being paid to the immense loss that is thereby incurred. Considerable heat energy has to be used to convert the ores of iron into the commercial product, and we are already facing a greatly depleted coal supply. At the same time we can readily find manufactured iron which, in long years of service, has shown very little decay due to corrosion. Something then is radically wrong with our present method of manufacture, and we of the present generation have no right to seriously deplete the coal supply of the next generation for a product that will not justify the investment. We have no right to erect structures and bridges of iron and steel which are not only not going to be financially profitable investments, but which, unless thoroughly protected from decay, will prove a menace to the community. Instead of striving for such remarkably rapid steps forward in the manufacture of iron we should step backward and find out why the old puddling process gave a product more resistant to corrosion than the modern rapid "Bessemer" and "Open Hearth" processes.

(2) Having solved the question of the manufacture of steel with respect to "quality" not quantity, it may be necessary to readjust our theory of stresses in proportion to the alloys of iron and design members according to their rate of corrosion under stress. That is, does a structural member tend to decay as rapidly under load as when unloaded, and within what load limits is corrosion a minimum? A study of the limitations of structural members from that point of view would seem to offer insurmountable difficulties from a practical point of observation. No one would be able to get any data on the rate of corrosion of an exposed structural member by examining it after erection and

during years of service. But here the electrolytic theory of corrosion appears to give a method of attack. If it is a question of potential differences between different parts of the iron, which may prove to be induced by the non-homogeneity of the metal inciting an electric battery action, then why should not the stress on a member be studied with respect to electrolysis?

(3) What is the connection between ordinary corrosion and the corrosion induced by the iron becoming the positive pole of a stray current? If the electrolytic theory holds true the latter

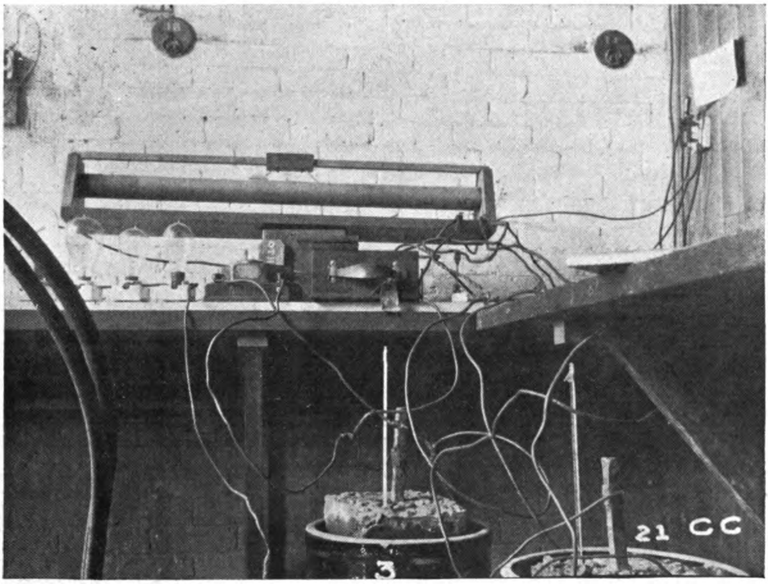


Fig. 2.

VIEW OF PRELIMINARY BLOCKS IN CIRCUIT.

is simply an aggravated case of the former. But a study of the aggravated case and its solution may give an entirely satisfactory solution of the case of ordinary corrosion.

The work of Messrs. Knudson, Nicholas, Glauber, and Eltinge plainly shows that concrete and cement, which give such a good protection against ordinary corrosion, are not to be relied upon for protection against currents of relatively high potential. This simply means that no concrete yet studied is entirely free from minute voids which not only hold water after

the concrete is set but also absorb water by capillary action, the same as ordinary stone. If, then, a block of concrete is always saturated when imbedded it is bound to be a good conductor for an electric current, its rate of conductivity being proportional to the existing voids and the concentration of the electrolyte. Thus the imbedded iron will decay in any case, provided the impressed E.M.F. is sufficient to carry the current through the concrete, as there is always enough area of surface contact between the iron and the concrete to be a means of ingress and egress for the current.

(4) If the concrete does not prevent this corrosion, and the former tests seem to show that is true, what can be done to minimize this action? The question of the stress on the member has already been mentioned. The next point of attack would appear to be either waterproofing the concrete or protecting the iron by an insulating film. It is along these lines that the problem was attacked, and the results proved so interesting that a short discussion of the conclusions is given below.

The points investigated were divided into three heads:—

A. A study of the action of stray currents on unstressed, imbedded steel. These tests were extended to include an investigation of the insulating properties of several waterproofing films and compounds.

B. A study of the rate of corrosion of steel under stress.

C. A study of the effect of setting cement on paint films.

Corrosion of Unstressed Steel.

For preliminary work two blocks were made as shown in Fig. 1. These blocks were arbitrarily numbered 3 and 21. The concrete mixture was known, the blocks were studied for density and percentage of voids and the mechanical and chemical properties of the iron were known.

The two blocks were put in circuit and so wired that to complete the circuit the current had to flow from the iron to the water in the voids of the concrete and thence to the return wire wound around the bottom of the blocks. Upon closing the circuit it was found that current could be detected at any impressed potential within the limits of the apparatus used. It was decided to use an impressed potential of 25 volts on block No. 3 and keep this voltage constant. Under this condition the average current during the test was 0.0769 amperes. Block No. 21

was wired in parallel with No. 3, and here the impressed potential was 3.4 volts and the average current during the test was 0.0159 amperes. The voltage impressed on block No. 3 is too high for practical stray current, but the voltage impressed on block No. 21 is well within the limits of practical experience.

Under these conditions the action which went on during the test was:—

(a) An apparent washing out of lime water from the pores of the concrete.

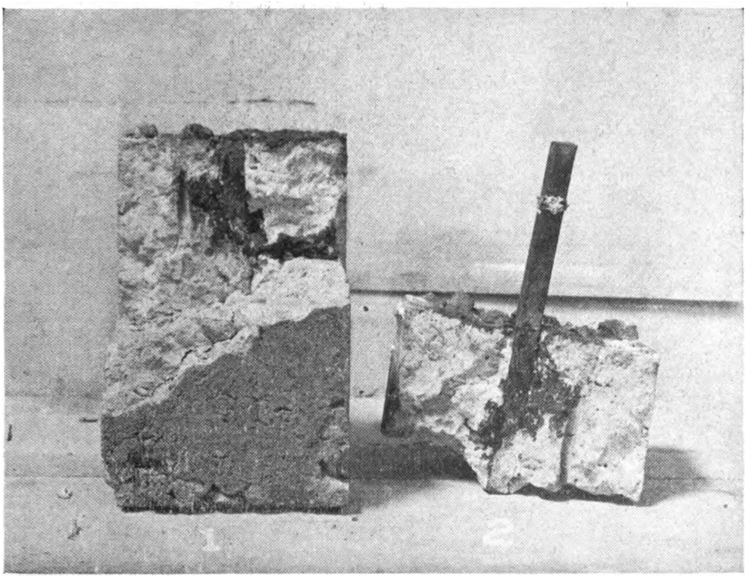


FIG. 4.

INTERIOR OF BLOCK No. 21.

(b) A gradual accumulation of iron hydroxide on the tops of the blocks, changing to iron rust.

(c) Finally a splitting of the blocks along well defined planes of cleavage from the top of the blocks down almost even with the bottom of the imbedded iron.

The condition of the interior of the blocks is shown in Figs. 3 and 4.

Block No. 3 was in circuit 2144 hours. Block No. 21 was in circuit 3196 hours.

The cause of the splitting of the blocks was attributed to the action of the strong oxidizing agents chlorine and oxygen permeating the pores of the concrete and in the presence of water changing some of the cement compounds to higher states of oxidation. Such a change would make more space necessary and so act as a bursting force. The presence of chlorine is due to the salt solution in which the blocks were set.

FIG. 5.

BLOCKS OF SECOND SERIES.

As a result of these tests it seems certain that a current as low as 0.015 amperes will not only seriously corrode the iron but will, in time, make the concrete protection useless.

To study further the effect of currents of even lower potential and amperage, eight more blocks were put in circuit and are now being tested. Figure 5 shows these blocks before being put in circuit.

In this test Block No. 31 has a waterproofing compound mixed with the water. Block No. 30 has a waterproofing com-

pound mixed with the cement. Block No. 4 is wired with the current in a reverse direction, namely, from the solution to the iron. Blocks No. 32 and No. 33 are similar to blocks No. 3 and No. 21. Block No. 20 has a hydrolythic cement waterproofing compound on the exterior. Block No. 35 has a linseed oil waterproofing compound on the exterior. Block No. 2 has a

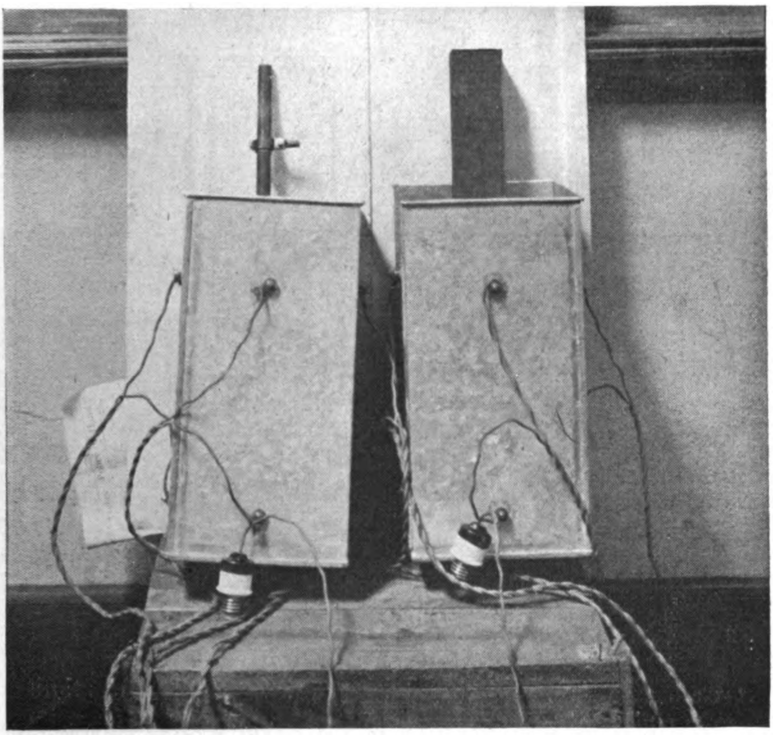


FIG. 6.

COMPRESSION AND TENSION BARS READY FOR TESTING.

bitumen waterproofing compound on the exterior. Each block of the series showed a current as soon as it was put in circuit and the maximum and minimum conditions of the test to date are:—

Maximum potential 2.4 volts.
Minimum potential 0.74 volts.
Maximum current 0.000623 amperes.
Minimum current 0.000096 amperes.

It is seen that these currents are so small as to be almost negligible so that the results on these blocks will define very clearly the limits for further experiment.

Corrosion of Steel Under Stress.

The object of this series of tests was primarily to discover whether steel under stress corroded as rapidly as unstressed

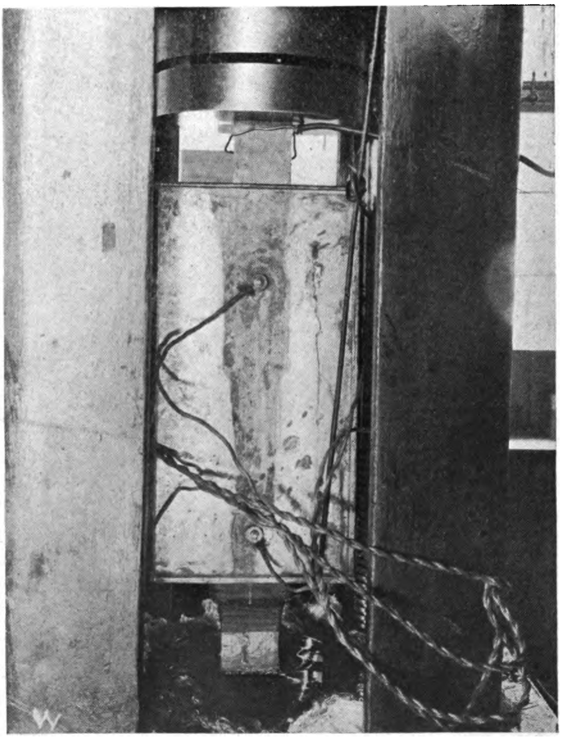


Fig. 7.

COMPRESSION BAR IN MACHINE.

steel, and in combination with the results obtained from the imbedded tests to gain some idea of the effect of stray currents on steel under actual working conditions.

Small tension and compression bars were secured and inserted in cans containing an electrolyte as shown in Fig. No. 6.

These bars were then inserted in the testing machine and a current passed from the iron to the liquid and out through the binding posts at the side of the can. Fig. 7 shows a compression bar in the machine.

The results of these tests are shown in Fig. 8 where the rate of corrosion per ampere hour is plotted as ordinates and the stress in pounds to which the member was subjected at the beginning of the experiment as abcissae.

The results of the compression specimens are plotted to the left and the tension specimens to the right. A study of these plots would indicate that there is a decided difference in the rate of corrosion between stressed and unstressed bars within the

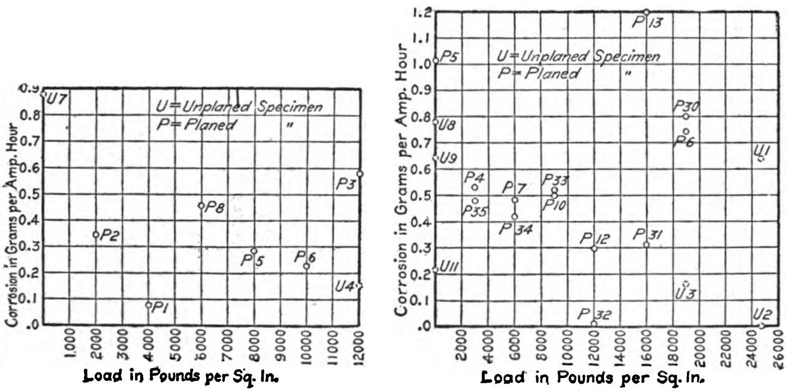


FIG. 8.

CORROSION VALUES FOR COMPRESSION AND TENSION BARS.

limits of ordinary working conditions. In each case the rate of corrosion appears to first decrease as the load increases and then the rate of corrosion increases rapidly as the stress goes beyond the working strength of the material.

Figs. 9 and 10 show the results on some of the tension and compression bars respectively. The necking down of the bars near the bottom shows the amount of corrosion.

This series of tests will be extended by further research work.

EFFECT OF SETTING CEMENT ON PAINT FILMS.

This series of tests was started to determine the protection which iron preservative paint films afford against the action of

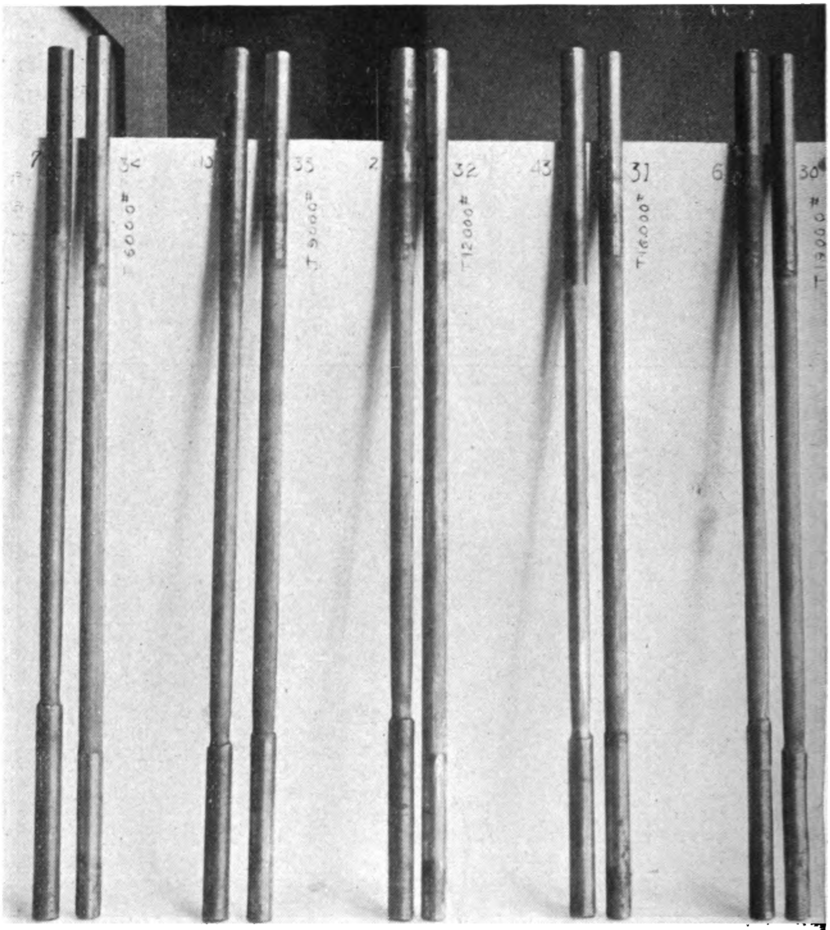


Fig. 9.

TENSION BARS AFTER TEST.

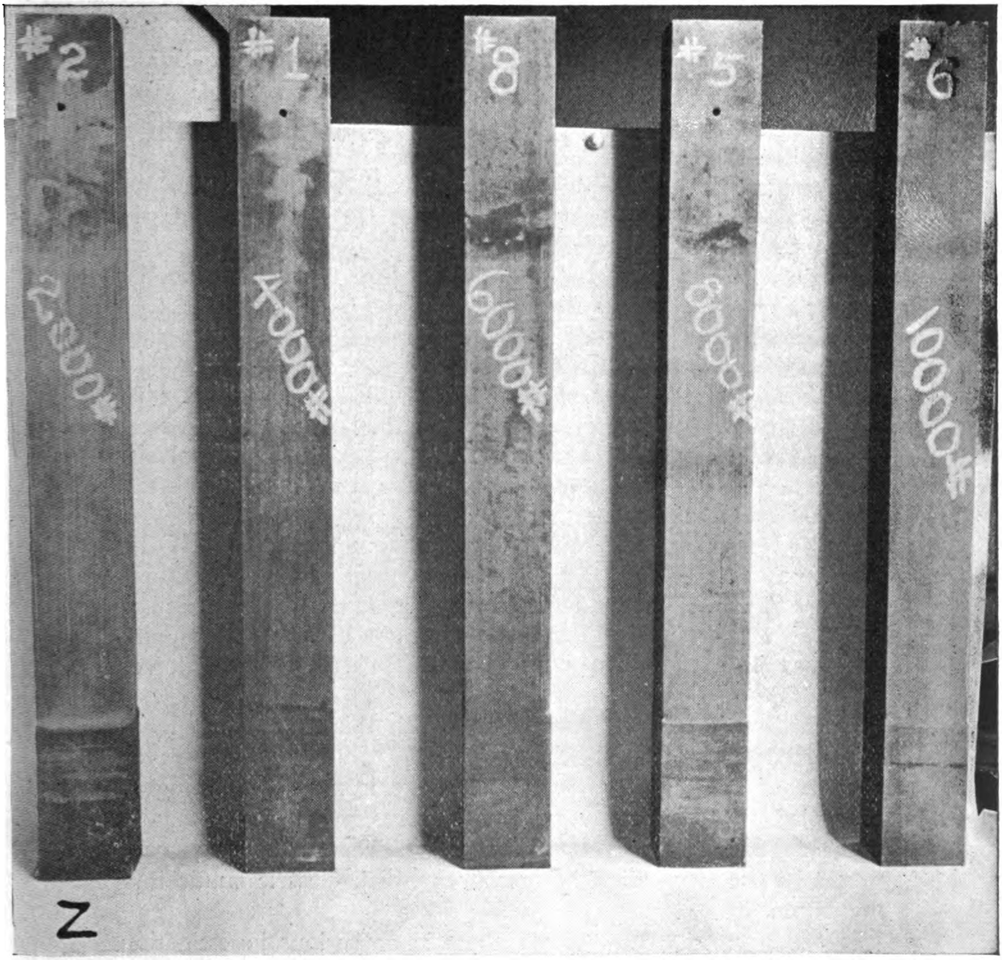


Fig. 10.

COMPRESSION BARS AFTER TEST.

stray currents, provided the film had been used to protect imbedded iron. About fifty of the best known iron-preservative paints were examined. Two separate methods of testing were tried. In the first method iron bars were painted and imbedded in neat cement and carefully examined after the cement had thoroughly set. In the second method the paint films were subjected to a high voltage until punctured, then the same films were immersed in calcium hydroxide and again subjected to the puncturing test. The results indicated that none of the paints tested fulfilled the following conditions:

(A) A paint film to be of value must be sufficiently elastic to stand considerable abrasion.

(B) The film must be of such a nature that it will not be attacked by the alkali in the cement.

A short compilation of results is given in the Engineering Record of July 30th, 1910.

The results of these experiments applied to practical conditions would show that the present method of protecting steel from corrosion is not adequate if there is danger of electrolysis.

There are two conditions under which corrosion due to stray currents could occur: —

(a) If a current became grounded from the interior of the structure.

(b) A stray current from an outside source, in seeking the point of lowest potential, might enter at one point of a structure and leave the steel framework where the earth was at a lower potential.

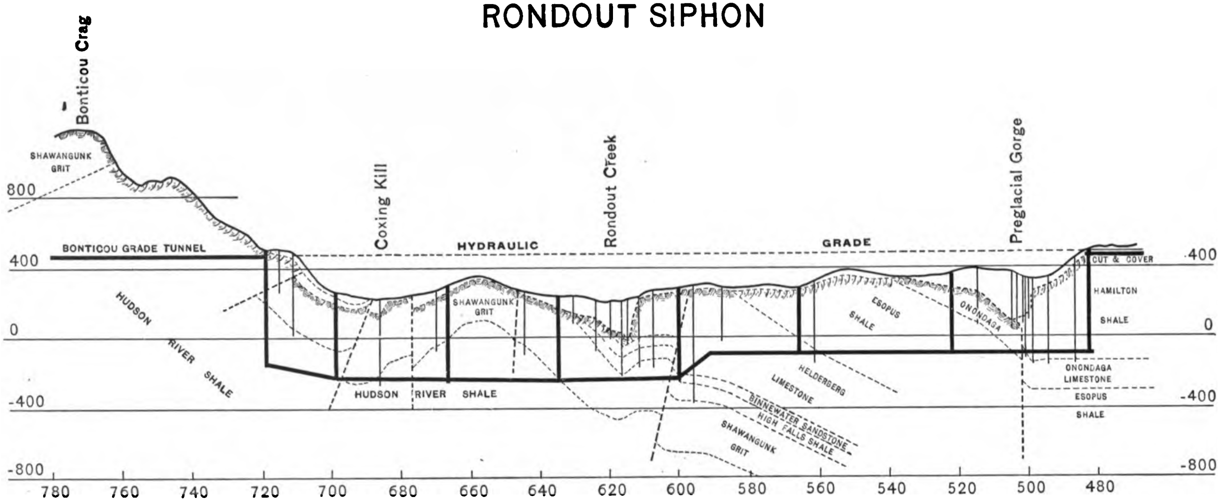
The three classes of structures which this would affect are reinforced concrete structures, building columns and the anchorage of big bridges. In all cases the iron is so thoroughly concealed that any corrosion which takes place might readily cause failure before it is discovered. The most serious case would be the suspension bridges over which electric traffic is a maximum.

As the question now stands there is no serious investigation of the subject. Different brands of cement should be studied with respect to their protective qualities, which is a study of the chemistry of cements. The different alloys of iron and steel should be studied with respect to metallographic structure and also with a series of tests similar to the tension and compression corrosion tests outlined above, in order to know which grade of

steel would be best for columns or anchorage arms imbedded in concrete adjacent to the soil. Paint films of the high grade baking varnishes should be studied to secure a film which will remain intact when imbedded, and yet have a high electrical resistance.

It is thus seen that the question involves theory and practice, mechanics and chemistry. Co-operation of engineers versed in practical observation is needed with the men in the testing laboratory. The danger of failure from corrosion increases as the number of bridges carrying high voltage traction lines is increased. The tests necessary are not of a character which can be taken up by college men in the ordinary course of college work. Time tests of long duration and accurate observations of results can only be made by men giving their whole time to the subject, and they should be in a position to make practical observations on the large bridges to determine whether stray currents do exist. They should also have free hand in a fully equipped testing laboratory, so as to make the maximum number of tests consistent with the importance of the subject.

RONDOUT SIPHON



Solid lines show borings, thus

Profile of Rondout Siphon
Showing Location of
Borings & Proposed Tunnel Grade
SCALE HOR. 1" = 2000'
VERT. 1" = 400'
March 14, 1908.

DEEP TUNNEL ALIGNMENT FROM SHAFTS

BY HERBERT M. HALE, '04

Assistant Engineer, New York Board of Water Supply.

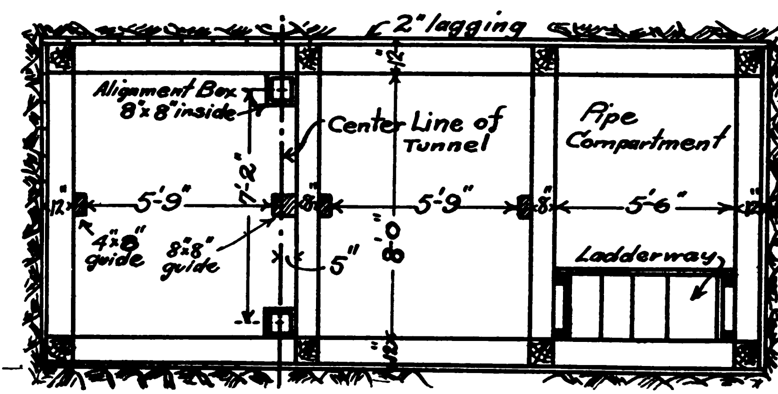
Surveying underground is, next to boring investigations, attended by the greatest feelings of uncertainty on the part of the engineer. Particularly is this true where underground surveys are connected to surface surveys by means of shafts. Transferring a surface alignment to a tunnel calls for exceptionally careful work within the shaft, the limits of which determine the length of the shaft base line, and any error in the bearing of the base line is greatly multiplied as the underground work advances.

A great deal of this kind of surveying is necessary in the work for the New York Board of Water Supply in its project for furnishing Catskill Mountain water to New York City. The valleys of tributary streams to the Hudson River cross the line of the aqueduct. The economic construction for crossing most of these valleys is by a tunnel through solid rock. Because these valleys are so far below the hydraulic gradient of the aqueduct, the pressure tunnels or siphons have been located so as to have a minimum of about 200 feet of solid rock over them to withstand the hydrostatic pressure from within.

The most northerly of these tunnels is the Rondout Pressure Tunnel. Its profile shows two preglacial gorges, each worn about 200 feet into the underlying rock, and it was in order to pass the required minimum of 200 feet below them that the tunnel grade was fixed as shown. Likewise the left-hand half of the tunnel beyond Station 600 was influenced by the desire to fall below the porous High Falls shale and to keep as far as possible in the Hudson River shale, an easier tunnelling rock than the Shawangunk grit, which is practically pure quartz. Thus the northerly or right-hand half of the tunnel is from 100 to 104 feet below sea level, and the southerly half from 220 to 250 feet below sea level. The tunnel, nearly four and a half miles long, with an excavation diameter of about 17 feet 6 inches and a clear diameter of 14 feet 6 inches inside the concrete lining, is being constructed from eight shafts varying from 380 to 710 feet in depth. The end shafts are waterway shafts of the same size as the tunnel,

Shaft No. 1 being the downtake and Shaft No. 8 the uptake, the former having a top elevation 16 feet above that of the latter. Shaft No. 5, the drainage shaft, is located 75 feet to one side of the center line, and is connected with the tunnel by a drift, in which will be installed the valves and door necessary for the relief of pressure before unwatering the tunnel.

The alignment of the tunnel is a straight line from Shaft No. 1 to Shaft No. 7, with a slight angle to Shaft No. 8. For the final monumenting of the line, the right of way was cleared and primary monuments established at the ends near Shaft No. 1 and Shaft No. 8. A primary monument midway was set by "bucking" the instrument into the line of the two end targets. Similarly a monument was set at each quarter-point on the line



CROSS SECTION OF CONSTRUCTION SHAFT.

by using the end and middle line monuments. From these smaller divisions two control monuments were set by use of shorter sights. All line work within the shafts was in general dependent upon the control monuments. The straight alignment of the whole eliminated the troublesome work always found in railroad tunnels or curves.

All shafts except Nos. 1, 5, and 8 are construction shafts and will be finally sealed with concrete sufficiently far above the tunnel as to form an effective plug. The construction shafts, a cross-section of which is given in the cut, have the smaller width along the tunnel center-line. This shaft width of eight feet in the clear makes a base line of only a little over seven feet between the centers of the alignment boxes, which are eight

inches square inside and extend down to the tunnel. This short base line compared to the distances between shafts, the distances varying from 2,000 to 4,400 feet, together with the shaft depths, is the one feature which determined the use of two general methods of dropping line, namely, those by

1. Weighted piano wires.
2. Shaft transit and sighting board.

Weighted Piano Wires

This method followed the ordinary tunnel practice of setting two piano wires on the center-line at the top of the shaft and getting the direction of the same line at the bottom by a transit set in that line produced.

For the purpose of adjusting the hanging wires, special reels were made, consisting of a reel for winding in the wire, and a small sheave wheel which worked at right angles to the direction of the center-line of the tunnel by means of a slow-motion screw fitted with a set-nut. With a small weight on the end, the wire was unreeled, passing over the small sheave wheel and down the shaft in the center of the alignment box. When weighted at the bottom of the shaft with a twenty-pound weight and submerged in a large can of water, the wires were set with the slow-motion screw, by a transit fifteen feet from the shaft and on the center-line of the tunnel. It was customary below ground to have two transits, each about twenty feet in the tunnel from the near wire. When each transit had been adjusted to sight in line with the two wires, readings were obtained in both tunnels on a brass scale set firmly by hangers into the roof. Two settings of the transit were made, then the wires were thrown off line by means of the slow-motion screw on the reels, brought back into line again, locked by the set-nuts, and the foregoing operations repeated.

Every means was employed to eliminate instrumental error, both above and below ground; the wires were inspected throughout their length, and the instrument men changed about. Little difficulty was encountered due to the swinging of the wires, yet the observations took time, for the swing of the pendulums of such length as used was very slow. When the two transit vertical hairs coincided with the apparent centers of swing of the two wires, the scale readings were taken.

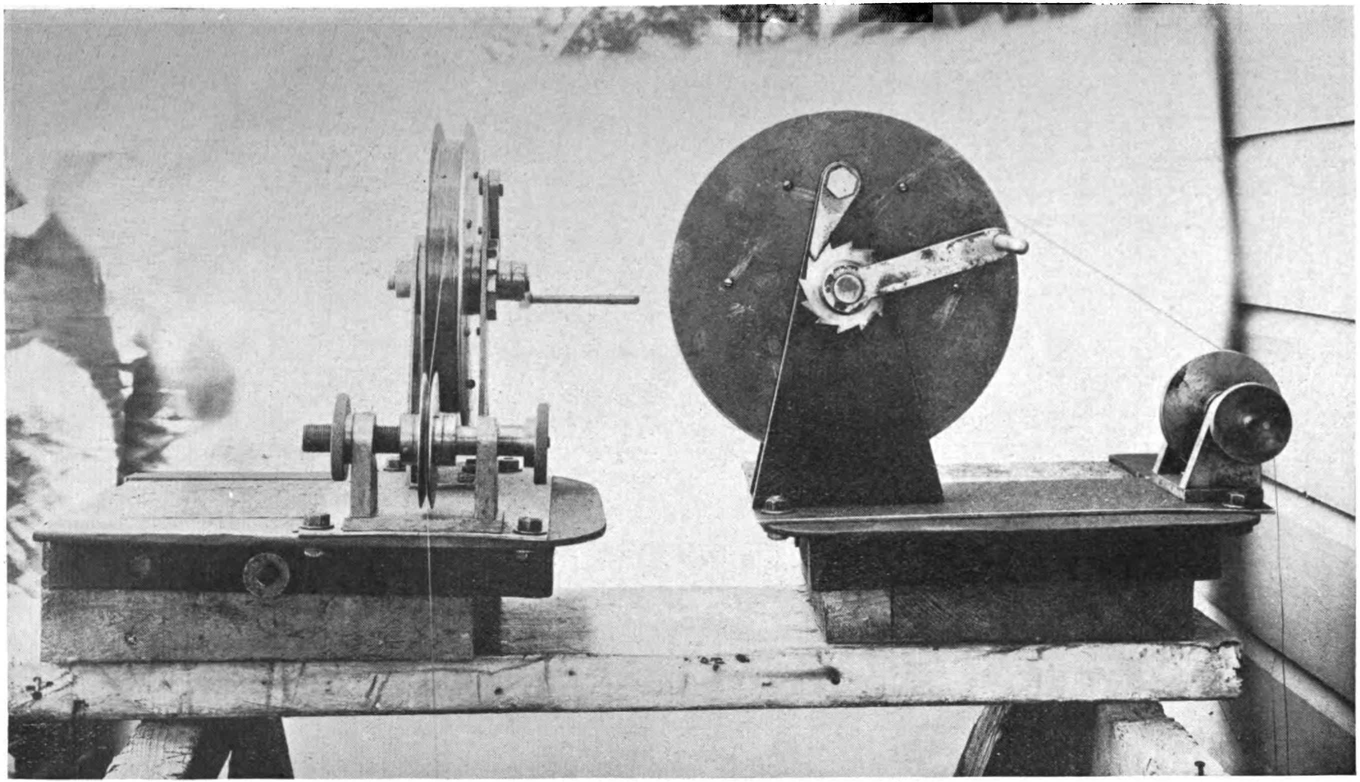
Pendulum Method for a Check Line

While the wires were hung from the reels, the line obtained in the tunnel was further checked by the direct application of the pendulum principle. In this instance the weights on the end of the drop wires were taken out of water and the pendulum allowed to oscillate freely in the air. A scale for reading the amplitude of the pendulum swing was secured, as close as possible behind each wire, to posts or other timber.

The extreme readings of the swings were taken, likewise the time for each set of five swings. When the pendulum swung around sufficiently to cause the wire to strike the scale, it was stopped swinging, pulled again to one side and set in motion for another set of readings. Averaging the scale readings for both scales gave two points from which roof scale readings were obtained in both tunnels.

As a check on the freedom of the wire from contact throughout its length in the shaft, the time of oscillation was compared with the theoretical time for a pendulum of the same length. The comparison was extremely close, and, as shown after the headings from adjacent shafts met, the line thus obtained would have been sufficiently good to carry the tunnel alignment throughout.

The disturbing elements in the use of the foregoing methods are the spattering of water on the wires, air currents in the shaft, and material in contact with the wires at some part of their length. Falling water spattering from the shaft timbers causes vibrations of the wire, which are usually more pronounced in one wire than in the other. Air currents, probably of a spiral tendency due to changing from the tunnel to the shaft, have more of the effect of making the pendulum oscillation of the two wires relatively unbalanced. The wires in deep shaft work must be very carefully inspected to avoid contact with stray nails or splinters of wood which are nearly always present. For this reason, to insure absolutely perfect inspection, the alignment boxes were finally made of three sides, with the fourth open the entire length. This inspection must be made also after the weights in the water have come approximately to rest. The writer has sometimes found that when the wire comes in contact with the wet side of the alignment box for part of its length, the adhesion to the wet surface has been sufficient to hold the weighted wire to one side of the true position of the point of suspension at the reel.

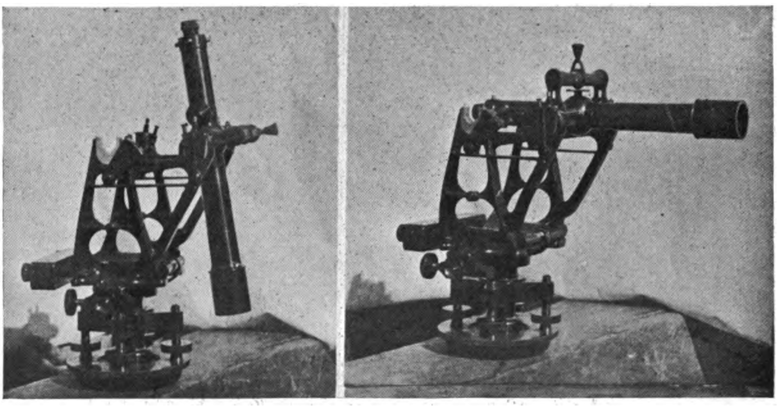


REELS FOR SUSPENDING WEIGHTED PIANO WIRE.

Shaft Transit Method

A special vertical sighting shaft transit was manufactured for this work by C. L. Berger, it being a modified form of the general type of mine transits, after suggestions of Mr. James F. Sanborn, '99, Division Engineer, Board of Water Supply.

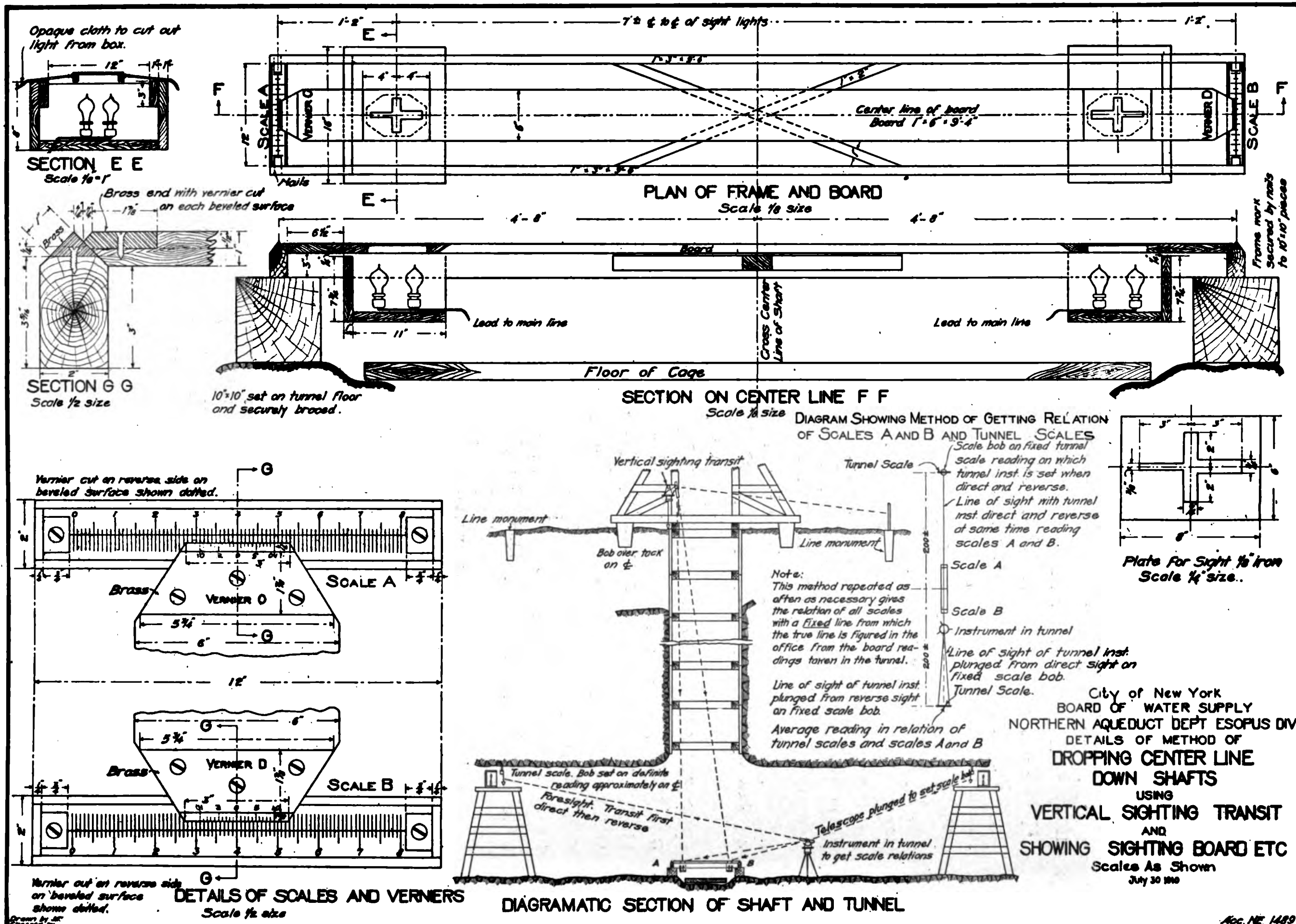
The transit consists of a heavy standard having a double set of telescope bearings, one directly over the center of the instrument and the other about five inches forward of the center. The telescope is detachable, to be used in either set of bearings. When in the center set of bearings it is an ordinary transit, when in the forward set the line of sight passes by the base of the instrument, thus sighting vertically down the shaft. To counterbalance the weight of the telescope in the forward bear-



SHAFT TRANSIT.

ings, an iron weight is fitted to the opposite of the transit base plate. Fitted with an extra striding level and the four-screw levelling system the instrument can be operated very easily.

With a good shaft transit at hand, the method of its application presented some study. It was found that in England an illuminated stretched wire in the tunnel, passing across the bottom of the shaft, had been adjusted into the line of sight of the instrument at the top of the shaft. Still another method used was to set two boxes having a black **X** on the illuminated faces, on some arbitrary line at the bottom of the shaft. The shaft transit was then set into line of the two crosses, and this line relation with the true surface line determined. The correction thus found was afterward applied to the arbitrary line in the tunnel.



Opaque cloth to cut out light from box.
SECTION E E
Scale 1/8"=1'
Brass end with vernier cut on each beveled surface
Brass
SECTION G G
Scale 1/2 size
10"x10" set on tunnel floor and securely braced.
7' 2" ¢ to ¢ of sight lights
SCALE A
VERNIER C
VERNIER D
SCALE B
Nails
Center line of board
Board 1" x 6" x 9' 4"
PLAN OF FRAME AND BOARD
Scale 1/8 size
4'-8"
4'-8"
Board
Lead to main line
Lead to main line
Cross Center Line of Shaft
Frame work secured by nails to 10"x10" pieces
Floor of Cage
SECTION ON CENTER LINE F F
Scale 1/8 size
DIAGRAM SHOWING METHOD OF GETTING RELATION OF SCALES A AND B AND TUNNEL SCALES
Tunnel Scale
Scale bob on fixed tunnel scale reading on which tunnel inst. is set when direct and reverse.
Line of sight with tunnel inst. direct and reverse at same time reading scales A and B.
Scale A
Scale B
Instrument in tunnel
Line of sight of tunnel inst. plunged from direct sight on fixed scale bob.
Tunnel Scale.
Note:
This method repeated as often as necessary gives the relation of all scales with a fixed line from which the true line is figured in the office from the board readings taken in the tunnel.
Line of sight of tunnel inst. plunged from reverse sight on fixed scale bob.
Average reading in relation of tunnel scales and scales A and B
Plate for Sight 1/8" iron
Scale 1/4" size.
Vernier cut on reverse side on beveled surface shown dotted.
SCALE A
VERNIER O
Brass
SCALE B
VERNIER D
Brass
Vernier cut on reverse side on beveled surface shown dotted.
DETAILS OF SCALES AND VERNIERS
Scale 1/2 size
Vertical sighting transit
Line monument
Line monument
Bob over tack on ¢
Tunnel scale. Bob set on definite reading approximately on ¢
Foresight. Transit first direct then reverse
Telescope plunged to set scale bob
Instrument in tunnel to get scale relations
DIAGRAMATIC SECTION OF SHAFT AND TUNNEL
City of New York
BOARD OF WATER SUPPLY
NORTHERN AQUEDUCT DEPT ESOPUS DIV
DETAILS OF METHOD OF
DROPPING CENTER LINE
DOWN SHAFTS
USING
VERTICAL SIGHTING TRANSIT
AND
SHOWING SIGHTING BOARD ETC
Scales As Shown
July 30 1910
Acc. No. 1489

In the Rondout shafts a stretched wire in the tunnel was first tried. The shafts are so deep that there was found to be no satisfactory means of illuminating the wire for direct setting. The wire, about three hundred feet long, supported so as to pass just below the roof scales in each tunnel heading, was set over the centers of two illuminated cross-cut holes in a sighting board similar to that shown in one of the cuts of this article. In this particular case the board had no end scales. The board was set on line from signals from the instrument man on top. This method presented the difficulty of adjusting the wire over the center-line of the illuminated crosses. Having also to alter the catenary or sag of the wire by tension at the ends, so that the wire all but touched the board, proved very troublesome. By a process of elimination of one defect after another, the independent method was finally worked out and used. This is shown in an accompanying drawing.

The sighting board with the crosses is fitted with a bevelled vernier at each end, one reaching left to right, the other from right to left. On the reverse bevelled faces are similar verniers having the same zero points. The line connecting the zeros of the verniers passes through the center of the crosses. This movable sighting board operates on two scales, reaching in the direction of the verniers, the scales being secured to the ends of the frame supporting the whole.

Setting up the apparatus consists in fastening the frame by nails to rigid timbers in such a manner that the center-line of the frame *approximates* the tunnel center-line. With a transit set approximately in the tunnel line and about twenty feet from one end of the frame, a foresight is taken on any fixed reading on the roof scale in the far tunnel. A reading is then taken direct on the two fixed frame scales with the same transit, the telescope then plunged and a reading on the back tunnel roof scale obtained by setting an illuminated plumb bob string or plummet lamp. This set of readings is repeated with the telescope reversed. The average of all readings on the four scales determines the Arbitrary Line from which the true line from the top of the shaft is subsequently figured. The relation of the scale readings is checked from time to time in the manner described.

The shaft transit at the surface, set on the true line, is sighted at one of the control monuments and thus directly throws the line down the shaft. The men at the board below

insert electric light clusters into the boxes of the frame under the crosses, then set the sighting board into position, by signal from above, so that the center of the crosses coincides with the sight of the shaft transit, whereupon the scale readings for both ends of the board are taken by the verniers. A number of readings, say ten, are obtained, then repeated with the telescope reversed, thus eliminating instrumental error which at the depth of the shafts would amount to considerable if the transit were not in good adjustment. A further precaution against error is to throw the transit off center, and re-set, after every twenty readings.

A sample of the notes appears in the following table:

READINGS OF BOARD AS SET BY SIGNALS FROM SHAFT TRANSIT

No.	Scale "B"	Scale "A"	Difference "B"—"A"	Groups No.	Groups Differences	Groups Average Difference
1	.269	.248	.021	1	.021	
2	.260	.241	.019	2	.019	
3	.257	.238	.019	3	.019	.020
*4	.277*	.235*	.042*	12	.019	
5	.218	.217	.001	20	.020	
6	.238	.242	—.004			
7	.224	.226	—.002	10	.006	
8	.225	.234	—.009	11	.008	
9	.257	.256	.001	16	.009	
10	.229	.223	.006	19	.010	.010
				14	.011	
11	.268	.260	.008	15	.013	
12	.241	.222	.019	18	.013	
13	.251	.256	—.005			
14	.259	.248	.011	5	.001	
15	.280	.267	.013	9	.001	.001
16	.259	.250	.009	19	.001	
17	.244	.243	.001			
18	.230	.217	.013	7	—.002	
19	.263	.253	.010	6	—.004	
20	.225	.205	.020	13	—.005	—.005
				8	—.009	

As before stated, the fixed scales at the ends of the frame read in the same direction, hence in the "Difference" column the comparison of differences indicates the swing of the board settings. The difference between differences indicates the amount which one setting lacks of being parallel to another in the board length. The "Groups" show how the "differences" cluster

* Disregarded

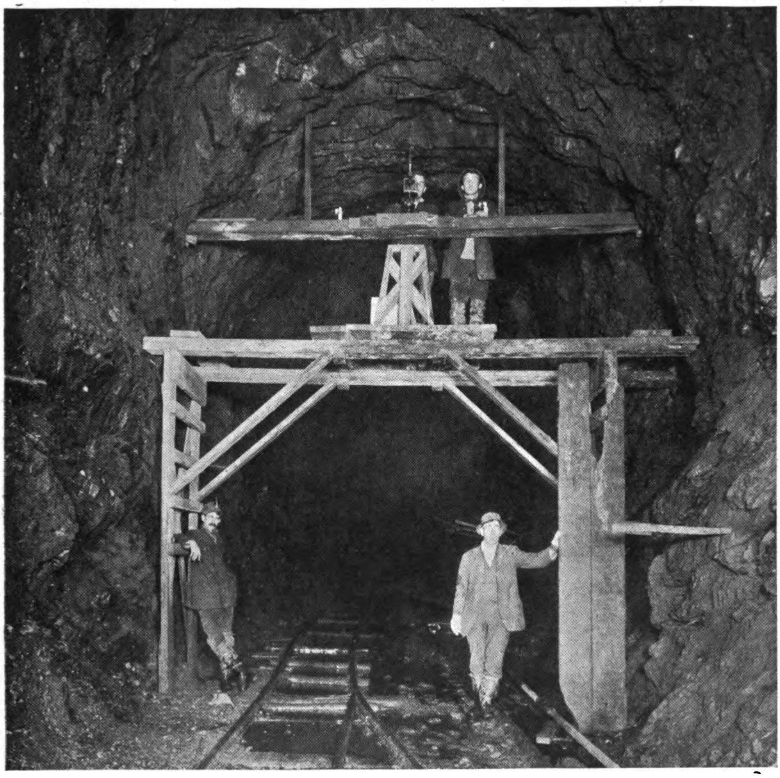
about certain averages, each difference varying but little from that average. In other words, the board in its settings swings in a fan-shaped manner, yet the separate groups of nearby parallel settings are quite equally weighted. The writer believes that with more powerful lights this particular set of notes would have been more generally consistent throughout. The line obtained, however, was a very good one. Reading No. 4 compares in position with no other setting or group of settings, and therefore was considered eccentric, and disregarded. From the average readings of scales "B" and "A" the true line in the tunnel scales can be determined from the relation of the four fixed scales embodied in the Arbitrary Line. This calculation is one of simple proportion after the distances between scales are known.

The Shaft Transit Method is by no means more intricate than the piano wire method. Its great advantage is in being an independent operation. Including the time to get the apparatus set up for work, one hundred settings can be made in three hours and a half under good shaft conditions. Two wire droppings, with one check dropping by the shaft transit, has been the procedure, thus using the shaft a minimum number of times, with a possibility of four times at the most. The writer is firmly of the belief that tunnel alignment from shafts has a tendency to be overdone. Sufficiently good alignment depends more on having used two independent methods than in the number of droppings. Too many droppings often result in one bad day's work varying so decidedly from previously good work as to cast discredit on the whole.

In the Rondout shaft droppings, more attention has been paid to getting tunnel lines such that the headings would meet within the limits of driving a rock tunnel. Therefore, if in three or four droppings the extreme lines produced, say for 2,200 to 2,500 feet to the probable point of meeting between shafts, showed a difference of anything under one foot, the average of the droppings was taken as the line from that shaft. All tunnel headings, at the time of writing, except those between Shafts Nos. 3 and 4, have met. The variations in the meetings of the headings were from three-quarters of an inch to eight inches, with the lines differing from zero to six inches from the true center-line between shafts.

The center-line in the first tunnel scales in the roof was prolonged on similar scales about 350 or 400 feet apart, put

in as the tunnels progressed. The prolongation was accomplished by centering the transit under one scale and sighting to the back scale, then throwing the telescope over. Several check runs were made in this way. It was found to be immaterial whether in prolonging the line the transit was set under the scale or "bunked" into line between two scales. Some



PRODUCING LINE FROM ROOF SCALE.

tunnel parties preferred the ordinary tunnel plummet lamps with oil wick flame for line work, while others used a plumb bob with the string set in contrast against white cloth over the face of an illuminated box. Granting that pressure tunnel meet within the allowable error for good work, the getting of grade in the tunnel is the more important of the two on

account of the slight grade for drainage purposes. Grade was carried down the shaft by the use of a weighted steel tape. All necessary corrections for weight, temperature, etc., were made in determining the bench mark below. The difference in grades after heading meeting was not over half an inch in any case.

The Shaft Transit Method as an independent check has since been used with equally gratifying results in the Wallkill Pressure Tunnel, having nearly the same depth of shafts as the Rondout.

The Rondout Pressure Tunnel of the Esopus Division in the Northern Aqueduct Department is being constructed under the supervision of Mr. J. Waldo Smith, Chief Engineer of the Board of Water Supply; Mr. Robert Ridgway, Department Engineer; and Mr. L. White, Division Engineer.

THE MARSEILLES DEVELOPMENT OF THE NORTHERN ILLINOIS LIGHT AND TRACTION COMPANY

BY CHESTER B. LEWIS, '07

The following article is intended to sketch in a brief way the development of water power at Marseilles, Ill., by the Northern Illinois Light and Traction Company, a subsidiary company of the McKinley System, which covers Central Illinois thoroughly with its lines. An article covering in detail the civil and hydraulic features of the plant will follow later in the year.

The company supplies current to the Chicago, Peoria, and Ottawa R. R., running from Princeton along the Illinois River to Morris, through LaSalle, Ottawa, Marseilles, and Seneca, with a branch from Ottawa to Streator; and also for commercial purposes. Along the Illinois and Michigan Canal is a 33,000 volt three phase transmission line carried on reinforced concrete poles, thirty to sixty feet long, of which the thirty foot poles are nine inches square at the bottom, tapering to six inches at the top; these are spaced about 125 feet apart, and carry two ten foot cross arms, attached by galvanized iron bolts and braces in holes formed in the concrete. Number 4 hard drawn copper wire is used. The current is transformed to proper line voltage direct current at five substations.

At present a steam plant is in operation at Ottawa, and a hydro-electric plant at Marseilles, the site of the development now under way. A small amount of power is also generated from water power at Ottawa. As the new plant will not supply all necessary power, it will run constantly at full load, while the Ottawa steam plant will be relied upon to supply the deficiency. The new plant, therefore, has been designed with a view to the greatest possible operating efficiency.

Water power development on the Illinois River has been given a considerable impetus by the Chicago Drainage Canal. It might be well to note here that although a treaty with Canada fixes the maximum withdrawal from Lake Michigan at 10,000 second feet, this will probably be revised to 14,000 second feet at the opening of the Sag Channel, draining the southern part of Chicago. The minimum flow is fixed by the population of

Chicago, and will steadily increase. At Marseilles, the water power rights, dam, and races, are owned by Mr. D. C. Boyce of Chicago, and were leased by him to several industries. As some of the leases had several years to run, the company took over all the leases for the sake of convenience, and now has the use of all the water not called for by the other lessees.

The electrical equipment of the plant is, in brief:

Six 300 K.W. 2300 volt direct connected umbrella type vertical A.C. generators driven by waterwheels; four of these are 25 cycle, the others 60 cycle. Two 450 K.W. 2300 volt 60 cycle horizontal shaft generators, each coupled through bevel gears to three vertical water wheels; these wheels and generators are in operation in the present plant and will be moved. In order to protect these machines from dampness, a metal diaphragm will be inserted under them. All are three phase. There will be three exciters: two direct connected to vertical water wheels, either of which will be of sufficient capacity for the whole plant; one belt driven horizontal machine which can be connected to the shaft of either of the 450 K.W. generators.

A space has been left for a future installation of another 300 K.W. unit. There will be a frequency changer of sufficient capacity to carry the whole output of the station. The Chicago, Ottawa and Peoria R. R. requires 25 cycle current, while the other demands, including that from the city water works at Marseilles, and those for commercial purposes, are for 60 cycle. The water works may be moved from their present location into a new building, and the pumps driven by motors, a point which at present has not been decided.

The switchboard and transformers are placed in an annex to the main building; the latter will be in two banks, one stepping up 2300 volt three phase 60 cycle current to 33,000 volts, the other stepping up the 2300 volt 25 cycle current to 11,000 volts; either transformer bank will be able to handle the entire output of the station. This arrangement together with the frequency changer provides perfect operating flexibility, and thorough provision is made for all possible combinations. The switchboard is arranged for remote control.

A new substation has just been put in operation at Ottawa containing three 200 K.W. 60 cycle 2300 volt—33,000 volt Westinghouse transformers, protected by electrolytic lightning arresters. Space is left for the duplication of the above. The

substation is about half a mile from the Ottawa power house; it can be operated either step up or step down, depending on the relation between loads and the output of the Marseilles and Ottawa stations.

To secure high efficiency it was desired to install the largest possible units. As only about twelve feet of water is available for the 72 inch water wheels, the speed is fixed at 72 R. P. M., making all the direct connected generators extremely heavy. However, a careful balancing of operating efficiency against first cost developed in favor of such an arrangement.

An electric 25 ton travelling crane will command the whole building with the exception of the switchboard and transformer annex. A railroad stub track will run far enough into the building to enable the crane to take shipments directly from the cars.

One feature of the station is the provision of a heating plant; a study of the heat losses which might be expected in the electrical apparatus showed that these could not be depended upon to keep the building warm in winter.

The building will have a tiled roof carried on steel trusses, with brick walls. The entire substructure and floors will be plain and reinforced concrete. Wiring will be led through reinforced concrete conduits under the floor.

Rigid economy has been insisted upon in all details, but a fundamental feature of the design has been an insistance that there shall be no skimping and that the entire work shall be up to the highest standards. Engineering problems have received an unusually exhaustive attention and the installation will be an excellent example of modern electrical power handling.

The design of the station was by Mr. C. W. Humphrey, of Chicago, Consulting Engineer for the company. The contract for the superstructure has just been let, and work will start immediately.

BOSTON'S NEW TELEPHONE RATES

AMES G. PATTERSON

Changes in telephone rates are no new occurrence, as it has been the policy of the New England Company to readjust rates from time to time, resulting in a price to the user very much lower than that of a comparatively few years ago, as shown on diagram (Fig. 1). The rates now being put into effect are particularly interesting as an example of state supervision, on account of

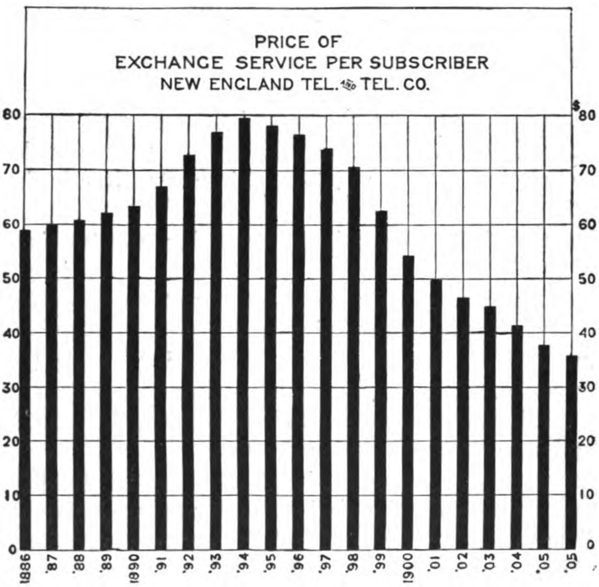


FIG. 1.

These stripes show by their length the prices of telephone service for the last twenty years. The necessity of doubling single grounded wires to double or metallic circuits and altering the switchboards increased the cost of the telephone, and then later improvements reduced the cost until it averages less than half what it was in 1894.

the methods by which they were deduced and the amount and character of the work required to make ready for their application.

THE OLD RATES

Before outlining the new plan, it may be well to describe the basis on which telephone service in the Boston and Suburban

districts was being given. The "Metropolitan" district covered an area of about four square miles, including seven exchanges, — Main, Fort Hill, Haymarket, Oxford, Richmond, Tremont and Back Bay. The "Suburban" district covered an area of 432 square miles, comprising 44 exchanges, as shown on map (Fig. 2). Rates were classified, according to service given, as:

Metropolitan and Suburban, or Suburban.
Business or Residence.
Special, or two-party or four-party or six-party line.
Unlimited ("flat rate"), or Measured, or Coin Box (prepayment).
Private branch exchange, short term; and other miscellaneous rates.

In connection with numerous rates for various combinations of the above classes of service, two points are most noteworthy. For the special line business rate of $162 per year, service was unlimited as to number of calls or destination within the Metropolitan and Suburban district. For Suburban rates in general, service was unrestricted as to destination within the Suburban district only, that is, a subscriber could call without extra charge to any Suburban exchange, but there was a charge of 10 cents per call to Metropolitan exchanges. Suburban rates were much lower than "Metropolitan and Suburban," the rate for special business line, unlimited, being $84. Residence rates which were very popular were the four-party unlimited for $30, and the six-party unlimited for $25, the latter an obsolete service retained by a limited number of subscribers.

By act of Legislature, effective on July 1, 1906, the Highway Commission was given supervision and control over "parties engaged in the business of transmitting intelligence by electricity in the Commonwealth." On petitions of certain subscribers, hearings were given on the question of rates and service, both local and toll, in Boston and vicinity. As a result of studies by a committee of the petitioners assisted by the company, a new schedule was compiled for submission to the petitioners and the subscribers generally.

The Petitioners' Plan

Obviously, the unlimited feature, both in number of calls and in distance, resulted in greatly increased use of service, the cost of which must be borne by all subscribers, whether they made use of these privileges or not. In order to reduce the suburban

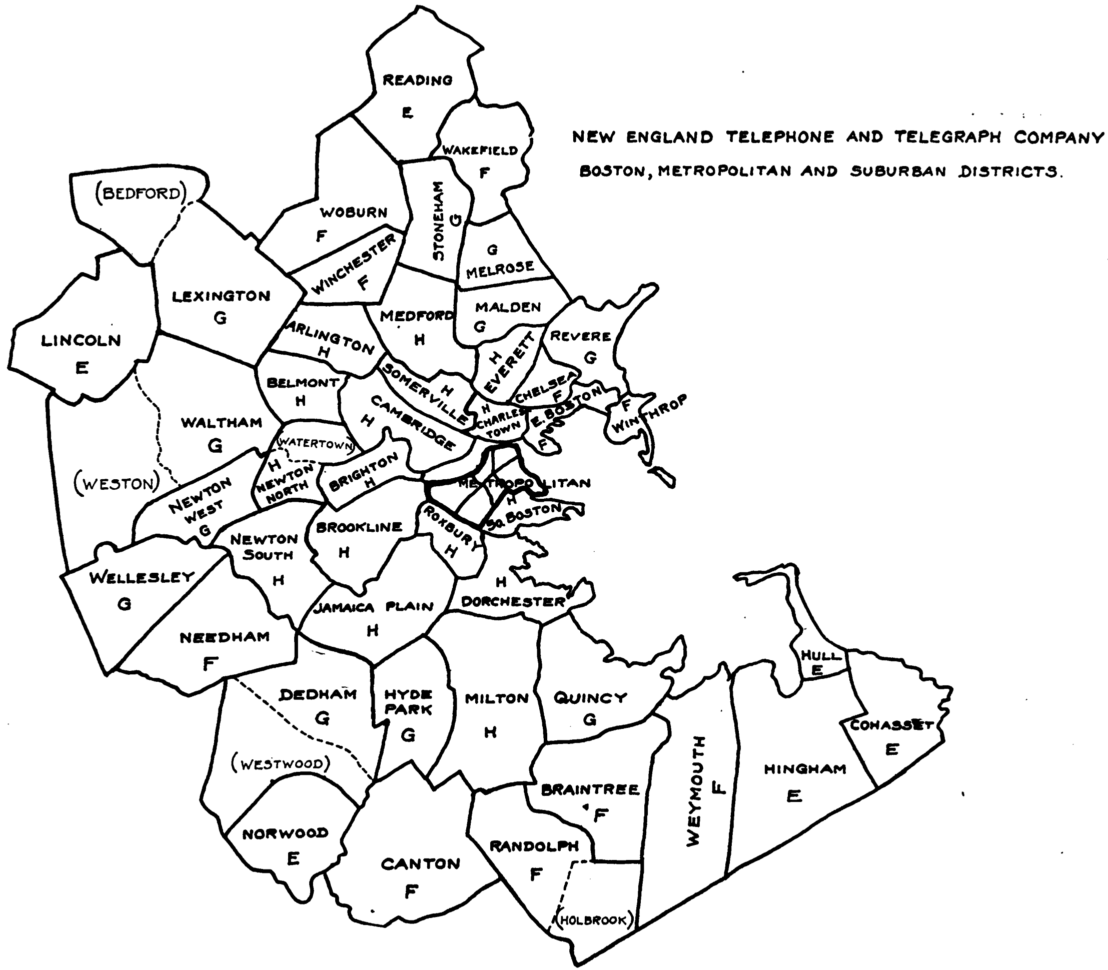

NEW ENGLAND TELEPHONE AND TELEGRAPH COMPANY
BOSTON, METROPOLITAN AND SUBURBAN DISTRICTS.
READING E
WAKEFIELD F
(BEDFORD)
WOBURN F
STONEHAM G
G MELROSE
WINCHESTER F
LEXINGTON G
MALDEN G
MEDFORD H
LINCOLN E
ARLINGTON H
H EVERETT
REVERE G
CHELSEA F
BELMONT H
SOMERVILLE H
H CHARLES TOWN
E. BOSTON F
F WINTHROP
CAMBRIDGE H
WALTHAM G
(WATERTOWN)
H NEWTON NORTH
BRIGHTON H
(WESTON)
NEWTON WEST G
METROPOLITAN H
SO. BOSTON
ROXBURY H
BROOKLINE H
NEWTON SOUTH H
WELLESLEY G
H DORCHESTER
JAMAICA PLAIN H
NEEDHAM F
HULL E
DEDHAM G
HYDE PARK G
MILTON H
QUINCY G
COHASSET E
(WESTWOOD)
WEYMOUTH F
HINGHAM E
BRAINTREE F
NORWOOD E
CANTON F
RANDOLPH F
(HOLBROOK)

Fig. 2.

rates, it was therefore proposed to divide the suburban district on the basis of preponderance of intercommunication. By this plan, each exchange, together with surrounding exchanges most frequently called, would form a district. All calls within the district would be included in the regular rate. For each additional two miles, an additional charge of one cent would be made. The regular rates for suburban, two-party residence service were to be $30 for unlimited service within the five-mile district, or $24 for measured service (480 calls). Four-party lines were to be abolished, and replaced by two-party lines with "divided ringing," by which device on two-party lines the bell of the party wanted, only, will ring, and not that of the other party. These latter changes would improve the service by decreasing the number of "line busy" calls, and the amount of party line interference. The rates between Metropolitan and Suburban offices were also to be reduced to five cents within five miles, and one cent per two miles additional.

The proposed schedule was not received with favor by a portion of the petitioners' committee or by some of the subscribers, — particularly those who had been making large use of the unlimited suburban privilege, practically at the expense of higher rates for other users. This plan was therefore abandoned and the hearings were continued. An expert accountant, Mr. A. R. Patterson, examined the books of the company, and in April, 1907, reported his findings as to financial conditions, methods of accounting, and proportions of various items of expenditure. On his recommendation, certain changes in accounting were put into effect. Officials of the company were called upon at the hearings for much information bearing on the question of rates.

In September, 1907, another report on accounting by Mr. George Albree was submitted and printed. After some eighteen hearings had been given, extending over several months, it was decided that some more systematic method must be pursued. In its annual report for 1907, the Commission said:

"The telephone rate problem is one of the most complex problems ever given to a public board to solve. It has received the most careful consideration by officers of and experts in the employ of the companies and apparently the business and other interests have been taken into account. The telephone to-day reaches every village in this Commonwealth, and the business is dependent upon good service and reasonable rates. Extension cannot be made without new capital; new capital cannot be had unless there is a good prospect of a fair return. Every interest is so interdependent that a disturbance of any kind may cause great inconvenience, annoyance, and even loss.

"Whatever the commissioners may do in the matter of recommendations as to rates will not be done until the facts and figures which are before them have been carefully studied, and studied with the aid and advice of business men and of experts on accounts, on construction and on operation. The magnitude of the problem leads the Commission to believe that it is justified in taking all the time that is necessary to solve it in a manner that will satisfy the subscribers, the public, and the stockholders of the company."

Professor D. C. Jackson, of Massachusetts Institute of Technology, a leading expert on electrical matters and president of the American Institute of Electrical Engineers, was selected to report on three questions: the first, whether an inventory and appraisal was a necessary preliminary of a satisfactory solution of the rate question; the second, whether, without prejudice to the general problem, there could be a reduction of the toll rate from the Suburban district of Boston; the third, whether it was possible and advisable to change the multi-party lines of the Boston and Suburban Division to two-party lines with divided ringing.

Professor Jackson's Plan

In March, 1908, Professor D. C. Jackson reported his findings, which were, in brief, as follows:

1. An inventory and appraisal of the company's property is necessary to a satisfactory solution of the rate problem. It should be executed by the Telephone Company, under the supervision of engineers employed by the Highway Commission. It should subdivide the property so that a "distribution of expense depending on investment may be correctly made amongst the different classes of service."

2. In regard to the second question, a preliminary reduction from ten to five cents in the toll rate between subscribers' telephones in the Metropolitan district and subscribers' telephones in all exchanges within a radius of five miles from the center of gravity of the Metropolitan district was recommended.

3. The change of "multi-party" line service to two-party service was stated to be desirable, but as it was involved in the general rate problem, was recommended to be deferred until after the appraisal and gathering of cost and traffic data.

These recommendations were followed. The reduction from ten to five cents was put into effect the next month. The Legislature appropriated for the inventory and appraisal $30,000, to be repaid by the Telephone Company, and work was begun on a minute examination of all the company's property in the state. This was carried on both from records in the offices and by

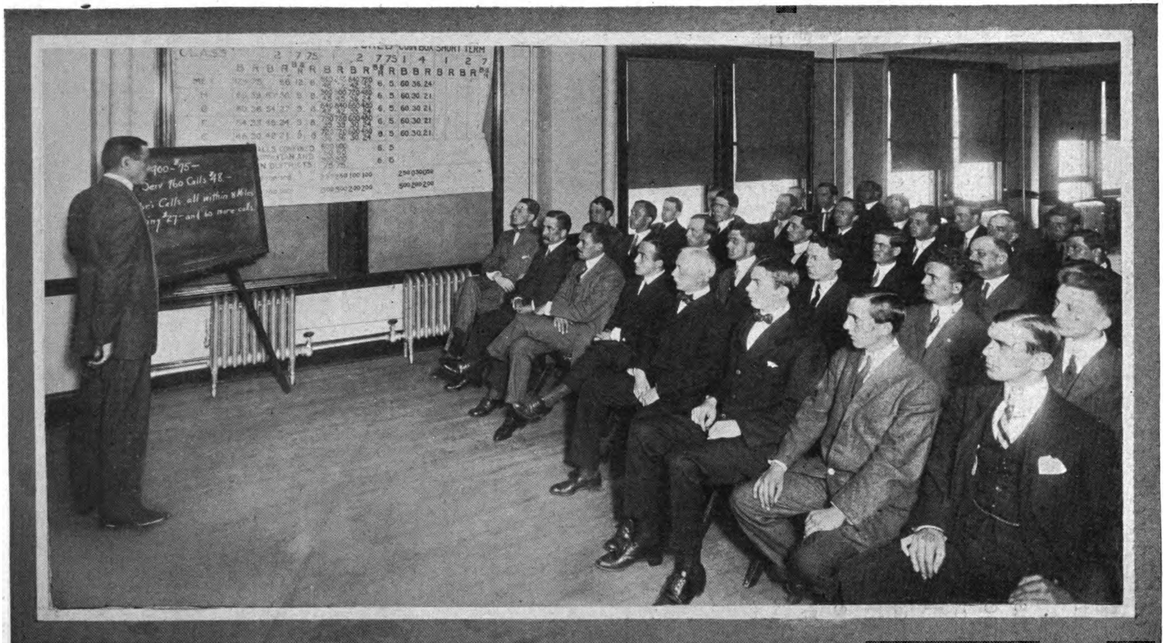
means of field work; *i.e.*, actual inspection and count of the items of property. The work was directed by the well-known engineer, Mr. Hammond V. Hayes, in co-operation with Professor Jackson. Nearly a year was required and a vast amount of data was accumulated, the documents being sufficient to fill a large room. For the proper study of this material, as well as of traffic and financial data, a further sum of $35,000 was appropriated by the Legislature. The amount which the company has repaid to the state treasury is over $43,000, in addition to which the company has expended several times as much in co-operative work. The inventory and appraisal, which was completed in March, 1909, was, at the request of the company, extended to cover Maine, New Hampshire, and Vermont. The results were as follows:

Appraisal value of entire property of the New England Telephone & Telegraph Company...	$46,540,819
Total par value of company's outstanding stocks, bonds, and notes, as given by the company's auditor for August 31, 1908.............	38,939,850

This showed an actual replacement value of property nearly twenty per cent in excess of the par value of all certificates of indebtedness outstanding.

In February, 1910, a report was submitted by Professor Jackson, covering the results of the analysis of appraisal, of expense accounts, and of traffic study, so far as it applied to the Boston District. In its printed form, this report occupied sixty-six pages, beside numerous tabulations and diagrams. After a discussion of the size of the district, the diverse requirements for telephone service and the existing rates, Professor Jackson had the following to say regarding suitable rates:

"An equitable system of rates should distribute the burden of expense which must be borne by the company for operating, maintenance, depreciation and interest, between the users, with reasonable consideration of the proportion which is caused by the service in each of the several classes; and the classes of service should be sub-divided in such a manner that subscribers with relatively similar wants will naturally group themselves together in classes of service suitable to their needs. In this manner it is practicable to provide classes of service attractive to the greatest number of possible subscribers, at the same time eliminating the opportunity for individual subscribers to obtain their telephone service largely at the expense of others; and the burden of expense for operating, maintenance, depreciation, and interest which must be met by the company may be distributed with reasonable equity between the classes. This cannot be accomplished with flat-rate service covering large areas peopled by diverse populations. There is, however, reasonable justification for flat rates in



CONTRACT AGENTS AND DAILY SCHOOL WHERE REVISED RATES ARE STUDIED.

small zones within which classes of service may be composed of subscribers having largely similar wants. We therefore consider it practicable and right to make up a zone system with relatively small areas, and apply flat rates as well as measured rates to local service within those several individual areas, but with additional charges for all messages passing across the border of any zone." *

It appeared from the study of traffic and costs that "the average rates paid per message in the various classes of service range from substantially two cents per message to nearly eight cents per message."* The lower rates referred to applied to the single-party unlimited business service covering the entire Metropolitan and Suburban district, and also to four- and six-party residence, unlimited in suburban district only, the six-party being an obsolete service retained by some subscribers. Although only the larger users in the classes referred to obtained their service at the lower figure, it was evident from an analysis that "certain large users in each of these classes are obtaining their telephone service substantially at an expense to the other telephone users."*

In accordance with the principles quoted above for an equitable system of rates, a schedule was submitted (and later, with some modifications, accepted). It was proposed to constitute a system of local districts or "zones." The seven Metropolitan exchanges are taken as one definite district. The suburban districts consist of the exchange of the subscriber originating a message, together with the contiguous suburban exchanges (Fig. 2). These forty-four suburban districts, one for each exchange, thus overlap so that neighboring suburban subscribers are always included in the same district. The rate for exchange service covers messages to any subscriber within the local district, thereby avoiding the difficulty arising from arbitrary lines separating neighboring subscribers. For messages to points outside the local district a toll charge is made of five cents to exchanges within eight miles (originally proposed as seven and one-half miles) air line distance from the originating exchange. For Metropolitan exchanges, the distance is taken approximately from the "telephonic center of gravity" of the district. For each additional eight miles, or fraction thereof, an additional charge of five cents is made. Although the area included in the local service district is much less than under the old plan, yet it is found that aside

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* Report to Massachusetts Highway Commission on Telephone Rates for Boston and Suburban District, D. C. and Wm. B. Jackson, Feb. 14, 1910. Printed for the Commission.

from messages to Metropolitan exchanges (which were not included in local suburban service under the old plan) only 14 per cent of the messages are to exchanges outside the originating local district.

For the local district plan, other important advantages are claimed. As the districts include various numbers of telephones, it is possible to provide different schedules according to the extent of the local service offered, giving lower rates where districts are less developed, and in the more densely populated districts, rates which are properly higher in proportion to the extent of the service. As these districts develop telephonically under the district system, it is possible to readjust the rates in some districts without disturbing others. In classifying the suburban districts for this purpose, four grades are established. In the first or "H" grade are included those districts having between 10,000 and 25,000 stations; in the second or "G" grade, those between 5,000 and 10,000; in the third or "F" grade, between 2500 and 5000; and in the fourth or "E" grade, those districts having less than 2500 stations. The classification in which each district falls is shown in connection with the map (Fig. 2).

On account of the inequality of flat rates covering a large diversified area, it was proposed to abolish all such flat or unlimited rates which applied to the entire Metropolitan and Suburban district, but to leave the flat rates in effect for service within the smaller restricted districts. It was recognized, however, that the message rate which charges each customer in proportion to service is the ideal method. It was also proposed not to provide any measured service covering the entire Metropolitan and Suburban district; but this was later modified by the Commission in apparent recognition of the propriety of such a service at a suitable rate.

Even after the general scheme of service and the allowable reduction for the entire area had been determined, the fixing of the exact rate for each class of service required a very careful analysis of the costs proportionately chargeable to each class. This part of the problem was handled in accordance with the principles for determining equitable rates, referred to above. The cost of furnishing service was considered in two parts: first, the "annual cost entailed by the investment," and second the "cost per message entailed in caring for the subscriber's traffic."

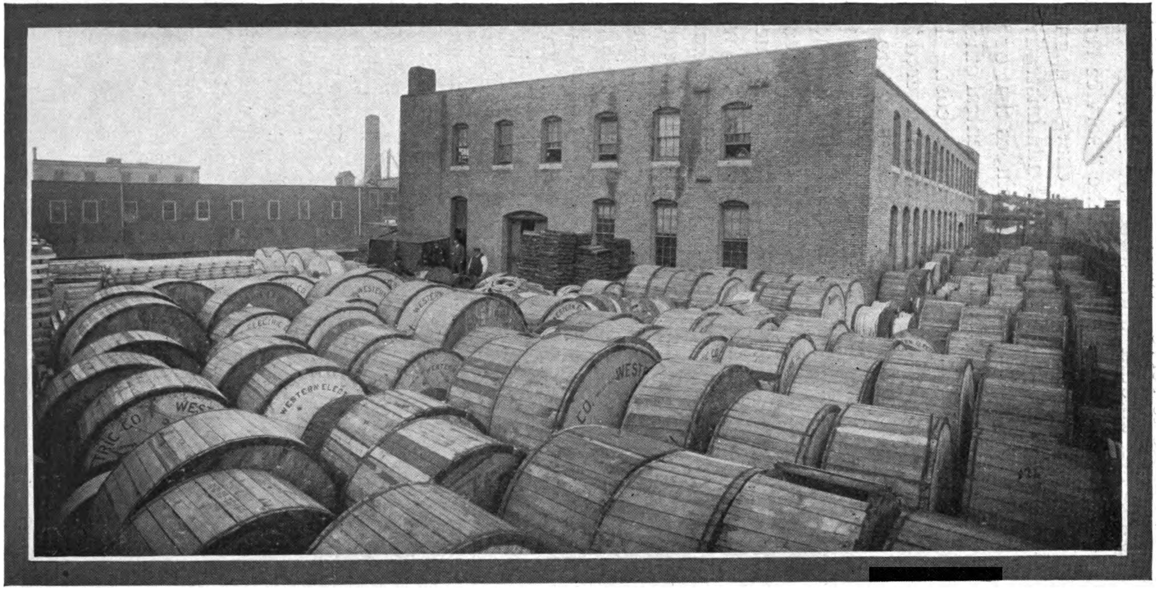
The investment cost itself is again divided into two parts, first, the cost required to give any service at all, — which may be

termed the "readiness-to-serve" cost; and second, the cost involved in giving the amount and speed of service desired by the particular user, which may be termed the "service rendered" cost. In each part are included the fixed charges upon investment, as well as repairs and operating and administrative costs. The "readiness-to-serve" cost in general includes that of the subscriber's instrument, the line connecting to the central office, necessary switchboard equipment, and central office cost. The cost which depends upon the amount of "service rendered" covers the additional switchboard positions necessary to handle the calls without delay, as well as the larger part of the cost of trunk circuits between offices. The operating and current costs of all kinds were determined from the records on the company's books and the investment from the values found by the inventory and appraisal. On the above basis, it was computed "that the minimum annual sum that the telephone company must now receive to meet interest and expenses entailed by the readiness-to-serve and service-rendered investment in the Metropolitan zone is practically $20 for the average subscriber to a four party coin box telephone, $39 for the subscriber to a single party measured rate business telephone and $80 for the average subscriber to a single party, flat rate business telephone."* It should be noted particularly that these figures apply to service in the seven city exchanges only, and cover merely the charges on investment, to which must be added the cost of caring for the traffic day by day.

This traffic cost was taken as proportional to the number of messages. It was recognized that certain messages such as those between subscribers in different exchanges may ordinarily require more operators to handle them, but the use of average costs was considered "reasonably just for the present study."

After considering the investment charges and traffic expenses there remained still the grouping of the users into average classes. "The classes of service should then be in sufficient number and cover a sufficient range of conditions to meet satisfactorily the requirements of any reasonably numerous group of subscribers."* The proposed schedule must also be flexible, that is, so framed as to allow readily of changes either in particular rates or in the whole schedule as might become advisable. By an application of such reasoning, suitable rates were determined for the various classes of

* Professor Jackson's report.



ABOUT 250,000 FEET OF CABLES RESERVED FOR RATE CHANGE REQUIREMENTS.

service in the various districts. For the measured service, rates were "based on a cost per local message not greater than five cents." Similarly the coin box rates were to be adjusted so that no user would be required to pay more per calendar year that five cents per local message, unless the amount collected from his box was less than the yearly guarantee. The above abstract presents necessarily in a very brief and incomplete manner Professor Jackson's theory and method of handling the problem. The yearly rates, according to classes of service and districts, are given below, with the exception of mileage, short term and miscellaneous rates:

SUMMARY OF THE NEW RATES

Metropolitan District:

Unlimited, one-party, business, $125; residence, $75; two-party, residence only, $66; Measured, one-party, business, 960 calls, $48; residence, 900 calls, $45; two-party, business, 840 calls, $42; residence, 720 calls, $36; Coin-box, one-party, business, $60; four-party, business, $36; residence, $24.

H District:

Unlimited, one-party, business, $69; residence, $39; two-party, business, $63; residence, $30; Measured, one-party, business, 900 calls, $45; residence, 900 calls, $45; two-party, business, 720 calls, $36; residence, 480 calls, $24; Coin-box, one-party, business, $60; four-party, business, $30; residence, $21.

G District:

Unlimited, one-party, business, $60; residence, $36; two-party, business, $54; residence, $27; Measured, one-party, business, 840 calls, $42; residence, 840 calls, $42; two-party, business, 660 calls, $33; residence, 480 calls, $24; Coin-box, one-party, business, $60; four-party, business, $30; residence, $21.

F District:

Unlimited, one-party, business, $54; residence, $33; two-party, business, $48; residence, $24; Measured, one-party, business, 780 calls, $39; residence, 780 calls, $39; two-party, business, 600 calls, $30; residence, 480 calls, $24; Coin-box, one-party, business, $60; four-party, business, $30; residence, $21.

E District:

Unlimited, one-party, business, $48; residence, $30; two-party, business, $42; residence, $21; Measured, one-party, business, 720 calls, $36; residence, 720 calls, $36; two-party, business, 600 calls, $30; residence, 480 calls, $24; Coin-box, one-party, business, $60; four-party, business, $30; residence, $21.

Combined Metropolitan and Suburban Districts:

One-party, measured, business, 600 calls, $60; residence, 600 calls, $60.

Excess Measured Service Calls:

In Metropolitan, H, G, F, and E exchanges, three cents each; combined Metropolitan and Suburban Service, 600 to 900 calls, five cents each; over 900 calls, three cents each.

PRIVATE BRANCH EXCHANGE RATES

Metropolitan or Suburban Service:

Rates include switchboard, one operator's set and two trunk lines for No. 1 and include switchboard, one operator's set and one trunk line for No. 2.

Business Rates. — No. 1, measured, 3000 calls, $144; No. 2, measured, 2500 calls, $105.

Residence Rates. — No. 1, measured, 3000 calls, $144; No. 2, measured, 1000 calls, $60; apartment house, measured, 5000 calls, $180.

Additional calls, 3 cents each; stations, per year, $6.00 each; additional Trunk Lines, per year, $24 each.

*Both metropolitan and suburban service.

Rates unchanged from old schedule.

The aggregate effect of these rates was estimated to be a decrease of from $300,000 to $400,000 in revenue from the existing number of telephones.

In spite of the large total decrease in revenue, it should be noted that this would not allow a reduction of more than about $3.00 per telephone if applied on an average basis, and in view of the abnormally low rate enjoyed by certain users, it is clear that an equalization of rates might easily result in such users receiving no reduction whatever. The carefulness with which such readjustment of the rates must be made was shown by the fact that a decrease from the 3½ cents actually collected on the average for each call, to 3 1-5 cents, would entirely wipe out the surplus for this district, leaving no reserve for emergencies. In addition to the loss of revenue, an increased investment of about $1,000,000 was expected to be required for additional equipment to change multi-party lines to two-party lines and to introduce divided ringing.

Consideration and Modification of Professor Jackson's Plan

The matter of new rates was given the fullest consideration, and public hearings were held at which representatives of the petitioners, of the Telephone Company and users in general were heard. The principles which guided the commission are outlined in the following extract from its letter to the company, dated August 23, 1910†:

"In attempting to work out a sound and logical basis for a schedule of telephone rates for the Boston and suburban territory, it seemed to the Commission that the following fundamental propositions were perfectly clear:

*Retained from old schedule.

† This letter is now issued in printed form.

That the district to be covered by a given telephone rate should be the territory generally used by the great majority of the subscribers therein, rather than a much larger territory, the greater portion of which is seldom used by the majority of subscribers.

That the company should collect its revenue for calls between more distant portions of the territory from those who make use of such service, rather than from those who use only local service involving the use of a much smaller portion of the plant.

That the suburban exchanges have of necessity so much occasion for calling into Boston and vice versa that the five-cent toll-rate between Boston and suburban exchanges should be extended to cover the greatest distance consistent with a well-balanced schedule and with fairness to the company.

That business service at least, except for essentially local service, should be placed on a measured basis; and,

That so far as it is possible to do so, the rate schedule should be so made as to furnish telephone service to the small user, at the lowest yearly charge that is fair and equitable, and, on that as a basis, adjusted to meet the requirements of the medium and larger user."

After giving due weight to the views of all concerned, the rates worked out by Professor Jackson were recommended with some modifications. The more important of these modifications are as follows:

The retention of measured service covering the entire Metropolitan and Suburban territory for single-party and private branch exchange lines.

The extension of the five-cent toll radius to 8 miles.

The counting of five-cent toll calls toward making up the guaranteed number of calls on measured service, within the Metropolitan and Suburban area.

The reduction of the present toll rate between adjoining exchanges on opposite sides of the suburban boundary, from ten to five cents for all distances not exceeding five miles.

With the modifications, the Commission believed that the new rates would result in improved service, more equitable charges, especially for small users, and eventually a substantial

increase in the number of subscribers. The company raised a number of questions, but expressed its entire willingness to make a fair trial of the new rates. In his letter of August 30, 1910, to the Commission, Col. J. N. Keller, President of the company, stated its position as follows:

> "Certain features of the proposed plan are new, and it is somewhat difficult to see just what they may lead to, or just what they may seem to establish in the way of precedents. In view of the fact that the company's objections are based more upon this uncertainty than upon any demonstrable conviction that the plan may prove to be unfairly burdensome, the company has decided to give the entire plan a complete and impartial trial. . . . This decision of the company is upon the assumption that its action is without prejudice and that experience may show the necessity for modifications or readjustments."

It was decided to attempt to furnish service under the new rates by November 1, 1910, to those desiring it, — the old rates remaining in force for six months thereafter.

When the acceptance by the company was published, together with the advertisements of the new schedule, applications for service under the new rates at once began to come in. At the same time, however, in spite of the petitions and numerous suggestions regarding the new schedule and changes in the old one which had been entertained by the Commission a number of objections to the new rates began to appear. Some of these, of course, were from users who had previously been receiving service at an unduly low rate. Others were from four-party and six-party line subscribers who were making large use of the unlimited suburban privilege and who felt that the new rate, even with improved service, would not compensate for the restriction of this privilege. In response to requests, the time for which the old rates for four-party and six-party line service might be retained, if desired, was extended to November 1, 1911. It should be noted, however, that of about 24,000 changes from old to new rates, up to November 26, approximately 5400 have been made on voluntary applications of subscribers who had four-party or six-party service.

Preparation for Putting New Rates into Effect

In undertaking to make the new rates available by November 1, 1910, the company committed itself to an immense amount of work in a very short time. To the probable effect of these rates and the amount of work involved in putting them into force, some consideration naturally had already been given. Estimates had been made of the probable number of changes

in service from multi-party to two-party lines, and of the increase in the number of subscribers. There was available the traffic study of 1909 made for the Commission, in addition to previous records of the company. The obtaining of these data involved, for example, special tickets for each of about 500,000 messages distributed among 51 exchanges and 30 classes of service. About one-half of this traffic was inter-office business. All computations were made in duplicate for the sake of accuracy. About 164,000 computations were required. The force occupied with this work included ten inspectors for supervision of the ticket work, 26 computers and four stenographers. Changes in party lines, rearrangement of districts, divided ringing, amounts of normal and new growth, were considered in their relations to the number of calls originated, calls handled per operator, amount of trunking between offices, and so on. On this basis, the amount of switchboard necessary to provide adequate facilities was estimated. Among the equipment requirements were about 150,000 additional multiple jacks in various offices; and in seven offices, entirely new equipment, as the capacity of the old was nearly reached and a change in type became advisable.

In the Plant Department, plans for construction were made. By expanding the existing organization, with a well-trained force as its nucleus, it was possible to take care of installing as many as 1000 telephones per day, although this number has not yet been required. Allowing for the stock of material on hand and delivery of new material, schedules by dates for the various exchanges were made covering the per cent of preparedness for expected changes. By rush work, the alterations necessary for divided ringing were made at 1000 operators' positions. By shortening the usual routine, additional cables and wires were placed where the requirements for new lines seemed likely to exceed the facilities available.

An educational campaign was begun the first of September, by means of newspaper advertisements in the form of bulletins, and circulars enclosed with the subscribers' bills, explaining the purpose and application of the new rates. Plans were made for handling the re-writing of over 125,000 contracts for service, as rapidly as possible. The number of applications for changes increased very rapidly, until it was a severe tax upon even the enlarged organization which had been provided. The plan of this organization is shown schematically in Figure 3.* Some of the most interesting features of this work are the special card

* From paper read by J. M. Barry, Oct. 21, 1910. *Telephone Topics*, November, 1910.

records showing all the particulars of each subscriber's contract and service; the instruction school at which the contract agents were trained; and the "order board" at which applications for changes in services are handled over the telephone by a force of eighteen men. At the instruction school lectures were given by specialists on various branches of contract work, such as "Salesmanship," "Revised Rates and Their Application," "Relations of the Company to the Public," "Comparisons of Cost of Service to Subscribers at the Revised Rates," and "Switchboard and Sub-station Equipment Required for the New Service." Other matters requiring special attention and care are the statistical work; the handling of orders for the installation of new service; and provision for changes in telephone numbers by means of blank pages in the directory, supplementary issues, if necessary, and special "Information" operators.

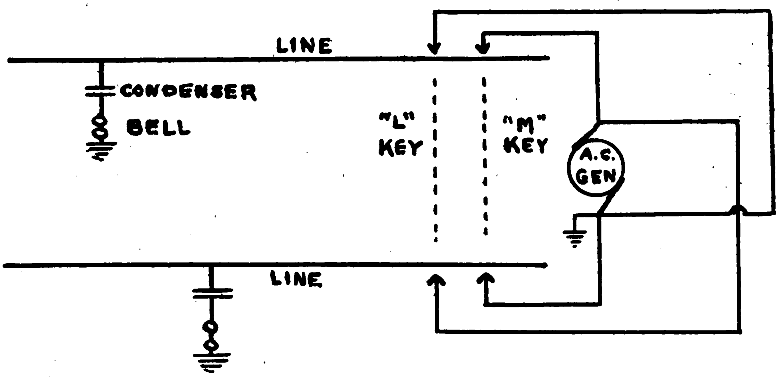


FIG. 4.

From the operating point of view, the additional work attending the change in rates is very considerable, owing to divided ringing, the use of letters instead of numbers to designate the parties on a party line, and the making of different tickets on the messages between districts under the new rates, necessitating the maintenance of practically two sets of operators in each office. Every possible precaution is planned to prevent the quality of the service from suffering while the changes are going on. In regard to the accounting methods, it is only necessary to recall the multiplicity of varieties of local and toll messages and classes of service under either old or new rates, and to keep in mind the fact that the two systems must be operated side by side for a year, in order to realize the burden imposed by this readjustment.

A few words in regard to the principles of divided ringing may be of interest. The parties on a two-party line are designated by the letters "L" or "M" appended to the line number, as "2507-L" or "2507-M." The power is supplied ordinarily by an alternating current generator at about 75 volts and 16 cycles. One side of the generator is grounded (Fig. 4). The connection is controlled by two keys on the keyboard in front of the operator. The two bells are connected from opposite sides of the metallic line circuit to ground. The operation of the "L" key connects the free side of the generator to one side of the line, ringing the bell on that side. The operation of the "M" key connects the free side of the generator to the opposite side of the line, ringing the other bell. In either case, owing to the ground on the generator, one of the bells will not ring. For the sake of simplicity, the telephones are not shown in the diagram, but they are connected across the line in the usual manner. The ringing is done, however, while the receiver is on the hook and therefore the circuit is open at the far end as shown. In using divided ringing on four-party coin-box lines, two bells are connected from each side of the line to ground and the operation of either key rings both bells on the corresponding side of the line. The distinction is made by the use of one and two rings, but the parties are designated by letters "L" and "M" for one ring; "R" and "J" for two.

From the preceding pages, an idea may be obtained of the fertility of the subject of the new rates. Extended articles might be written on the events leading to their adoption, on the determination of the rates themselves, and on the work of application. Under these headings, the best references are the annual reports of the Massachusetts Highway Commission, the letter of the Commission to the Telephone Company on August 23, 1910, the report of Professor Jackson, referred to above, and the educational advertisements in the Boston newspapers, beginning about September 1, 1910. The application and effect of the schedule are not yet matters of history, and even the plans for handling the work are merely indicated herein. The lists and map given are merely intended to afford a general idea of the scheme and not to take the place for prospective users of complete information and advice as to suitable class of service, which information is gladly given by the company at the offices, or by telephone.

OKLAHOMA CITY AND ITS OPPORTUNITIES FOR WORK FOR YOUNG ENGINEERS

BY ROLLIN E GISH, '07

A writer of conditions in Oklahoma is met at the outset by the conviction of the difficulty, that his statements to-day will be inadequate and out of date one year hence. This fact is well shown by the development of Oklahoma City within the last year. A picture of Oklahoma City and of its opportunities for the college man drawn one year ago would have failed to show most of those features for which Oklahoma City is remarkable to-day. In the construction of business buildings, for example, there has been a change from two and three story brick buildings to modern buildings of steel construction from eight to thirteen stories in height. At a time when Eastern banks were contracting their loans, when money on call in New York City was six per cent., and when a period of financial stringency was prevailing throughout the country, Oklahoma City was erecting no less than ten buildings of such a character, such as hotels, office buildings, and department stores. The architecture and construction of these buildings in every particular are taken from the latest and most approved of Eastern models. A total of two hundred and sixty-five business houses, and fourteen hundred and seventy-three residences were built in Oklahoma City within the last twelve months. New buildings and improvements of various kinds in Oklahoma City last year cost the sum of $5,903,270, an increase of 275% over 1908.

In industrial lines the development has been quite as marked. The last year has seen the advent of two packing plants, one of which was completed October 1st, at a total cost of construction of three million dollars, and another of equal size, now in process of erection. The plants being situated in a hitherto undeveloped locality near the city, have caused the growth of a new city about them, thereby involving the surveying and platting into lots of an area about ten square miles. Local capital has, so far, been unable to keep up with the demand for the construction of buildings and houses in this territory, thus created by the sudden influx of two thousand employes now at work in the new packing plant, which number will soon be increased to five or six thousand with the completion of the other plant.

As in many other new cities, the sanguine expectations of its "boosters" (this word is of Western coinage) led to what seems

like a very remote extension of the city limits. This has given rise to a great quantity of local engineering work in surveying good farms for the purpose of transforming them into none too desirable city blocks. This stretching of the city over a wide area has in turn necessitated a rapid expansion of the street railway service, so that at the present time there are forty-five miles of new track in various stages of completion. A great many young men from the engineering schools have been working in Oklahoma City, particularly during the summers, in the engineering department of the street railway and for the numerous engineers engaged in the laying out of new additions to the city.

The largest project, probably, in the engineering line in and about Oklahoma City, is the inauguration of a system of parks and boulevards surrounding the city. Within the last year the city has voted an appropriation of four hundred thousand dollars, which is the mere beginning of a plan to surround the city with a boulevard thirty miles in length which shall pass through the parks now laid out, and to be laid out, around the city. A recent report of the park commission shows that a complete line of levels has been run over the entire system; complete surveys, profiles, and location plans for the entire outer boulevard system, and surveys of the radiating boulevards and park ways, and also plans and specifications of all concrete culverts, bridges and arches, have been made. One of the largest features of the work is the construction of a concrete dam forty feet in height for the purpose of making an artificial lake northeast of the city. Connecting Packingtown and Oklahoma City a concrete bridge two hundred feet long and sixty feet wide has been begun, which, on completion, will be the main thoroughfare between these two portions of the city.

The next problem to confront Oklahoma City is the laying out of a site for the state capitol and the erection of a capitol building. The site now selected is about seven miles from the center of town, and the street railway company has agreed to provide a double track line and a ten minute car service.

To the man, however, who is seeking a business location the general business conditions of the city are quite as important as the specific items of work and progress. Oklahoma City has been made by its men and not by natural advantages, as will generally be found to be the case among the large cities of the West. The public meetings most largely and enthusiastically attended have been those called together for the purpose of raising a bonus that would secure some desired industry to the city. In this manner, two of the largest and best equipped packing plants

in the Southwest were secured, and the fight for the location of the state capital was carried to a successful issue. The business men of Oklahoma City have never hesitated to put forth time and money to get what they wanted for the city, and the result is that thus far they have succeeded in every undertaking. With all this expansion it is only fair to say that the bankers have shown conservatism which has checked the inevitable tendency towards an undue extension of credit. The last report of the Oklahoma City banks in the Clearing House Association shows that the percentage of cash reserves to deposits averaged forty per cent., which, I venture to suggest, will compare very favorably with the condition of banks in any portion of the country in this particular.

That characteristic most interesting to the college man contemplating a location in this section is the predominance of young men in business life. A Harvard 1904 man is head of the city water department; a 1908 man, an officer in one of the largest banks. Coming from the East I was especially impressed by the fact that young fellows who would be waiting their chance, like buzzards, in a large Eastern concern, are, in this country, managing smaller concerns, using independent business judgment, and undertaking the responsibility of large families. Business has not as yet fallen into well defined channels, for the reason that the large percentage of the business men are newcomers. The consideration of a man's father is rarely thought of, and all reference to such a remote ancestor as a grandfather would be tacitly avoided by mutual considerations of delicacy. The parting word which I would give to any college man seeking a location in Oklahoma is not to come without sufficient means to get back. There is, and has been, a great influx of young men from universities all over the country. The supply of young men who might be termed " adventurers " already greatly exceeds the demand for their services; and although there is, as I have indicated above, a great deal of work to be done, the engineers of this city are turning away many applicants for positions. A man must be able to remain here a sufficient length of time to form acquaintances, make the right connections, and find his opportunity. Once having found that opportunity, the Harvard man will find that there is a wonderful chance for development, and for the exercise of his special training, for the reason that in this country, there is no prejudice against an idea because it is new, and no limitation upon the man with new ideas because he is young, or because he or his family have been hitherto unknown.

HARVARD ENGINEERING JOURNAL

A QUARTERLY

DEVOTED TO THE INTERESTS OF ENGINEERING
AND ARCHITECTURE AT HARVARD UNIVERSITY

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The publishers of the JOURNAL take this opportunity of bringing before their readers again a subject touched on many times before in these columns. We want to get closer to our readers than we have been hitherto; we want to know what they think

of the publication, and we want them to help us to make it of the greatest possible value to the men of the departments of engineering and architecture, whether undergraduate or graduate. Every one who reads any periodical has his own ideas about it; where the publishers have failed, and where they have advanced. If each one of our readers would let us know his opinion, we should be able to advance much faster. Moreover, if another Harvard man is doing work of prominent interest as an engineer or architect, let us hear of it. If he can be persuaded to write it up, we should be glad to have it to publish. Above all, let us know about the small things which interest our graduates, and which never wander back unless one of you send them to us.

"The Harvard University Directory" appeared on November 30, and contains the names of 32,192 men now supposed to be living who have had some connection with Harvard University. The names and addresses are arranged both alphabetically and by states and towns. Over sixteen hundred men are listed as engineers and architects, distributed as follows:

Architects, 315; Civil engineers, 392; Electrical engineers, 284; Engineers (*unclassified*), 76; Mechanical engineers, 200; Metallurgical engineers, 110; Mining engineers, 227; a total of 1604.

The Directory may be obtained from the Publication Office, 2 University Hall, Cambridge, or at the office of the Alumni Association, 50 State Street, Boston. The price is two dollars, with thirty-five cents additional to cover postage.

ASSOCIATION OF HARVARD ENGINEERS

The greatest activity of the Association of Harvard Engineers for the last few months has been in connection with the registration bureau. Its close connection with the Appointments Office of the University and the interchange of information, both as to opportunities and calls for employment with the New York Society of Harvard Engineers, have given it an encouraging start. There are now on the employment cards of the Association over one hundred and fifty names, about a third of which are opportunities offered. The proportion of positions for teachers that have come to the bureau is much greater than civil, electrical, mechanical, or commercial, though these are represented, as well as miscellaneous work. On the other hand, few graduates register here for teaching work, being mostly taken care of at the University Office.

Considering the fact that the bureau has been established for so short a time, there has been a very fair success in securing men to fill the positions that have come up. Members of the Association, however, are earnestly requested to co-operate with the Secretary in making the bureau active and efficient. An application blank for keeping on file detailed information as to qualifications, etc., will be sent on request to members who are looking for employment or are contemplating changing their positions. Members who know of positions that are open are urged to inform the Secretary.

There have been two meetings of the Council since the last issue of the JOURNAL, one on Commencement and the other November 12. It was voted to hold the annual dinner early in March.

The following nominating committee for the coming year was chosen: H. L. Smyth, Chairman; A. F. Holden, Franklin Remington.

Twelve men were elected to membership at the June meeting and twelve this month, the names to be added to the membership list on payment of the first annual dues.

The membership of the Association has increased about ten per cent the last year, — the net membership being now three hundred and fifty-eight, about a third of which are life members.

Since the publication of the last membership list (in May, 1910), the following men have become regular members:

BAKER, MORRIS, A.B. 1894; S.B. 1905.
Civil Engineer. 110 N. Vermont Ave., Atlantic City, N. J.

BARNES, DONALD CARTER, A.B. 1902; S.B. 1904.
Sup't, Pawtucket Electric Co., Pawtucket, R. I.

CARROLL, HOWARD HASTINGS, S.B. 1902.
Instructor in Drawing, Tufts College.
15 Windermere Ave., Arlington, Mass.

GILMAN, ARTHUR E., S.B. 1907.
Secretary. 39 Fountain St., Medford, Mass.

JOSEPHS, LYMAN COLT, A.B. 1908.
With Westinghouse Elect. & Mfg. Co.
1027 South Ave., Wilkinsburg, Pa.

MASSEY, CARL FREDERICK, A.B. 1910.
Rochester, Minn.

NEWTON, JEWETT BLACK, A.B. 1910.
With J. R. Worcester, Boston, Mass.;
and Cohasset, Mass.

NORRIS, R. V. (*Columbia,* E.M. 1885).
Consulting Engineer and Lecturer on Coal Mining.
520 Second National Bank Bldg., Wilkes-Barre, Pa.

PAGON, WILLIAM WATTERS, M.C.E. 1910.
Computer. 1301 St. Paul St., Baltimore, Md.

PREBLE, J. JARVIS, S.B. 1910.
90 Church St., Waltham, Mass.

PROUDFOOT, ARNOLD SMITH, S.B. (M.E.) 1903.
With Standard Arms Co., Wilmington, Del.

RICHARDSON, HENRY ALLEN, S.B. (M.E.) 1907.
Mechanical Draftsman. 15 Highland Ave., Somerville, Mass.

STRONG, WARREN BOSTWICK, A.B. 1910.
35 Dana Chambers, Cambridge, Mass.

SYLVESTER, CARL A., A.B. 1902.
Gen'l Mgr., Street Railways.
797 Washington St., Newtonville, Mass.

TOWLE, FOSTER, S.B. 1906; A.B. 1907.
Civil Engineering. Fort Shaw, Mont.

WARREN, MINTON M., A.B. 1910.
105 Irving St., Cambridge, Mass.

WEEKS, WALTER SCOTT, A.B. 1906; S.B. 1907; M.E. 1908.
Teaching. 5 Grays Hall, Cambridge, Mass.

WRIGHT, CHARLES ALLEN, M.E.E. 1910.
1208 Adams St., Vicksburg, Miss.

Notice in Regard to Subscription of Members of the Association to the Journal

The annual dues of the Association have been found inadequate to carry with them an annual subscription to the Journal. Moreover, the postal regulations, as now interpreted, require a specific subscription and payment by each member in addition to his membership fee, if privileges of second-class matter are to be allowed. It was, therefore, decided that an annual subscription of fifty cents in addition to the regular membership fee must be charged to cover the cost of supplying the Journal. It is hoped that all members who have not already done so will send in their subscriptions before the beginning of another year.

Changes of Addresses

Barrett, N. M., Sec'y Irrigation Committee, Executive Bureau, Manila, P. I.
Begien, R. N., Asst. to Chief Eng'r, B. & O. R.R., Baltimore, Md.
Brinton, W. C., West Chester, Pa.
Brown, E. H., 716 Fourth Ave. S., Minneapolis, Minn.
Coffin, F. P., 223 Union St., Schenectady, N. Y.
Edwards, Harold, 702 Builders' Exchange, Winnipeg, Man.
Ely, F. B., Santa Rita, New Mexico.
Emerson, K. B., 165 Broadway, New York, N. Y.
Farley, F. C., 550 Park Ave., New York, N. Y.
Francis, R. S., Morris Bldg., Philadelphia.
Haskell, A. L., Sales Mgr., Pfanstiehl Elect. Lab., No. Chicago, Ill.
Herschel, W. H., 6 Cooke St., Providence, R. I.
Hills, O. S., 107 Clarendon St., Syracuse, N. Y.
Lincoln, H. L., 46-47 Winthrop Ave., Chicago, Ill.
Mason, Francis, 111 Broadway, New York, N. Y.
Morse, P. S., Mgr. Sulphide Corp., Ltd., Boularoo, N.S.W.
Olds, N. E., Care of P. & H. Supply Co., Fort Wayne, Ind.
Piper, W. B., Forest Service, Bozeman, Mont.
Pleasonton, F. R., Care of Penn. Steel Co., Steelton, Pa.
Pope, Frederick, 1016 Atlantic Nat'l Bank Bldg., Jacksonville, Fla.
Reed, W. M., 574 Palisade Ave., Yonkers, N. Y.
Rumery, Ralph R., 278 State St., Albany, N. Y.

TURNER, H. M., Supt. Power House Erection, Easthampton Gas Co., Easthampton, Mass.
WONSON, S. L., 179 Belmont St., Belmont, Mass.

All communications for the Association and the Registration Bureau should be addressed to the Secretary-Treasurer, F. L. Kennedy, Pierce Hall, Cambridge, Mass.

HARVARD ENGINEERING SOCIETY OF NEW YORK

The annual meeting and excursion of the Society were held on June 10. In the afternoon the members visited the plant of the Raritan Copper Works at Perth Amboy. A special tug-boat was chartered for the trip.

At the annual meeting held in the evening at the Harvard Club, the following officers were elected for the coming year: President, John R. MacArthur, '85; Vice-President, Francis Mason, '96; Secretary-Treasurer, Charles Gilman, '04. Executive Committee, John R. MacArthur, '85, Francis Mason, '96, Charles Gilman, '04, *ex-officio;* George S. Rice, '70, Franklin Remington, '88, B. B. Thayer, '88, three latest past presidents, *ex-officio;* Arthur C. Jackson, '87, Bernard R. Green, '64, A. W. K. Billings, '95, Stephen U. Hopkins, '97, M. H. Ryan, '99, Thomas Crimmins, '00, Roger C. Barnard, '02.

The first regular meeting and excursion for the year 1910-11 were held Friday, October 28. In the afternoon the Society made an excursion to the Brooklyn Navy Yard to visit the new Dry Dock in process of construction. Lieutenant F. R. Harris, Engineer of Construction for the Government, conducted the party. He was assisted by Mr. Clark, Superintendent for Holbrook, Cabot, and Rollins, the contractors. After viewing the Dry Dock, the party was conducted on board the battleships *Florida* and *North Dakota.*

The regular business meeting was held in the evening at the Harvard Club. Lieutenant F. R. Harris gave a very interesting talk on the history and design of dry dock construction.

The calendar for the year is as follows: —

Saturday, January 14, 1911. — Excursion to the new Grand Central Terminal. Meeting in the evening at the Harvard Club.

Address by Mr. L. G. Morphy, Designing Engineer of the Boston & Albany Railroad.

Friday, February 24. — Annual Dinner at the Harvard Club.

Saturday, April 15. — Excursion to the Astoria Gas Plant. Meeting in the evening at the Harvard Club. Address by Mr. W. C. Morris, Chief Engineer.

Saturday, June 10. — Field Day and Annual Meeting.

CHARLES GILMAN, *Secretary.*

HARVARD ENGINEERING SOCIETY

The first meeting of the year was held on the evening of Friday, November 11th, in Pierce 110. Mr. I. E. Moultrop of the Edison Illuminating Company spoke on "Central Power Stations."

Mr. Moultrop took up the principles of power station design as to position, size, type, and arrangement of boilers, prime movers, generators, and switches, showing how each of these was determined in the case of the L Street, South Boston, Station. The lecture was well illustrated with slides.

Owing to the absence from Cambridge of Mr. George W. Lewis, the President of the Society elected last May, a special meeting of the Executive Board was called in October to fill the vacancy. Mr. Lester W. Perrin, 2 G. S., was elected to fill the position for the year.

PHILIP C. NASH, *Secretary.*

HARVARD ELECTRICAL CLUB

A short meeting of the Club was held on November 16th to elect officers for the year. The results were as follows:

President: Chester W. Rice, 1 G.S.
Secretary: Hugh L. Davis, '12.
Treasurer: Barton Wheelwright, 1 G.S.

The prospects for a prosperous year seem very good, as several interesting meetings have been planned for the near future.

HUGH L. DAVIS, *Secretary.*

HARVARD MINING CLUB

The first regular meeting of the Club was held in the Assembly Room of the Union, on Friday evening, November 25th.

The meeting was opened at eight o'clock by President R. E. Somers, who introduced Professor E. D. Peters as the speaker for the evening. Professor Peters responded with an interesting talk on the subject of "Making a Start," taking for his illustrations many of his own earlier experiences.

Following the talk refreshments were served and new members enrolled. About thirty attended the meeting.

RAY P. DUNNING, *Secretary.*

HARVARD AERONAUTICAL SOCIETY

During the first year of the existence of the Society its members accomplished, in one way or another, most of the purposes for which the society was organized. A series of lectures on aeronautics was given; an aeronautical library was established; and a glider and aeroplane were constructed.

Owing to the fact that there were no suitable hills near Cambridge from which gliding could be carried on, the glider was used only in towed flights on Soldiers Field. The aeroplane, "Harvard I," was equipped with an engine which weighed twelve pounds to the horsepower; an engine entirely too heavy for aeronautic work. As the Society did not have sufficient funds to purchase a suitable engine, no real flights could be made with the machine. However, the failure of the machine to get into the air does not mean that it was a complete failure, for the members who watched and worked in its construction learned much which will be used to no small advantage in further construction work.

One of the ideas which the organizers of the Society had in mind at the beginning of last year was an aviation meet to be conducted under the auspices of the Society. Last summer the Manager of the Society, James V. Martin, Sp., succeeded in getting financial backing from a number of Harvard graduates in and around Boston, and the business management of the meet was turned over to Mr. A. D. Claflin, '86. After only six weeks of preparation, in which time a great deal of work had

to be done, the meet was held at Squantum from the 3rd to the 14th of September. It was at first planned to hold the meet on Soldiers Field, but as the entry list grew, this was found impracticable. Through the New York, New Haven, and Hartford Railroad Company an excellent flying ground was secured, with arrangements for the use of the field for a period of five years. The surface of the field was made level, grandstands were erected, and permanent and temporary hangars for the machines were constructed.

The management succeeded in securing for the meet some of the foremost aviators of the world. The entry list included Brookins and the late Johnstone, who flew Wright machines; Curtiss and Willard with Curtiss machines; Grahame-White and Harmon with Farman biplanes; and Roe with a Roe triplane. Grahame-White also flew a Bleriot monoplane. Other Curtiss and also Burgess biplanes were entered in some of the events.

Those who attended the meet were astonished at what a heavier-than-air machine can do; for at this, the first meet to be held in the United States, two American and one world's records were broken, and a general interest in aeronautics was aroused throughout New England. The meet was so generally covered by the press that it seems hardly necessary to do more than chronicle the records of the meet here:

Speed: Grahame-White, 5¼ miles, 6m. 1s.
Altitude: Brookins, 4,732 feet.
Duration: Johnstone, 3h. 5m. 40s. (American record).
Distance: Johnstone, 101 miles, 389 feet. (American record.)
Slow Lap: (5¼ miles) Brookins, 13m. 48s.
Getaway: Grahame-White, 26 feet, 11 inches.
Accuracy: Jonnstone (skids) 5 feet, 4 inches. (World's record.)
Bomb Dropping: Grahame-White, 180 points on 81 trials.
Boston Globe Course: (33 and a fraction miles) Grahame-White, 38m. 1 1-5s.

As a result of the meet an abundance of assets was left in the Society's hands. Besides its glider and aeroplane, it has the Roe triplane and a 30 h.p. engine with which to experiment; it has at its disposal the excellent flying grounds at Squantum and permanent hangars in which to store its machines. With the help of Mr. Claflin it hopes to turn the Harvard Aviation Field into a place for general experimental work and make it for Boston what Mineola is for New York.

The first meeting of the year was held on Tuesday, October 5, in Pierce 110. Professor A. L. Rotch, the president, presided; he touched upon the benefits which had ensued from the meet, although it had not been the expected success from a financial standpoint. He then introduced Mr. Claflin. who submitted the following financial report of the meet:

Receipts		*Expenditures*	
Gate receipts	$121,703.00	Aviators	$40,466.53
Miscellaneous receipts	6,564.17	Prizes	24,400.00
		Expenses	55,170.31
Total receipts	$128,276.17	Permanent improvements	30,124.71
Apparent deficit (*more than covered by permanent improvements*	21,894.38		
	$150,161.55		$150,161.55

Mr. Claflin stated that the small gate receipts were the result of the inadequate equipment, owing to the hasty preparations. It should also be remembered, in considering this statement, that this was the first meet of its kind in the country, and each new problem had to be solved at once, and perhaps not in the most economical way.

The Annual Meeting of the Society was held in the Assembly Room of the Union on the evening of November 28. The officers for the year were elected as follows:

President: A. Lawrence Rotch, h. '91.
Vice-President: James V. Martin.
Secretary: Edwin C. Brown, '12.
Treasurer: Arthur Sweetser, '11.
Directors: R. M. Allen, '11; P. C. Cummin, '12; R. Douglas, '12; H. L. Groves, '12; S. K. Rindge, '11.
Advisory Council: Professors H. N. Davis, '03; I. N. Hollis, h. '99; R. W. Willson, '73.

Manager Claflin of the Harvard-Boston Aviation Meet spoke of the results of the meet and suggested the possibilities of a similar but larger meet next year. He also presented a large portrait of Grahame-White, which the English aviator, unable to be present at the meeting, sent to the Society. Mr. A. A. Merrill described plans for a gliding slope which is to be erected at Squantum, and from which gliders can be safely launched for experimental purposes.

The Harvard Aeronautical Society plans to hold the first collegiate glider meet in the spring, and it hopes that the many college aero clubs now possessing gliders can be induced to

contest. The meet will take place on the field at Squantum and suitable cups will be offered as prizes in the different gliding events.

EDWIN C. BROWN, *Secretary.*

GRADUATE NOTES

(*On account of the many inquiries as to the whereabouts of the graduates of the department, it is hoped that the Editor will be notified of changes of address or occupation. Such notes will appear promptly in this column.*

Other notes of graduates will be found under the notice of the Association, in this issue.)

Arthur K. Adams, '04, is a mineral inspector for the General Land Office of the Department of the Interior, and is now stationed at Cheyenne, Wyo., examining lands in the Black Hills, S. D., and in Wyoming. Before taking up this work he was Professor of Geology and Mineralogy in the New Mexico School of Mines. Permanent address: Box 1153, Spencer, Mass.

R. L. Agassiz, '92, is Vice-President of the Calumet and Hecla Mining Company. Address: 12 Ashburton Place, Boston, Mass.

Holland E. Benedict, '03, is smelter superintendent of the Needle Mining and Smelting Company, Needles, Calif.

Gustaf S. Bohlin, '10, is an engineer on electrification work in New York City for the New York, New Haven and Hartford R.R. Permanent address: 103 Marion Street, Somerville, Mass.

Francis R. Bolles, '10, is with the Western Electric Company at Hawthorne, Ill.

Walter K. Cabot, '07, is mechanical engineer with the William Underwood Company, Canned Goods, Boston, Mass. Address: 16 Ellsworth Avenue, Cambridge, Mass.

Harold C. DeLong, '03, is with the Boston Transit Commission, with headquarters at 75 Canal Street, Boston, Mass. Address: Hotel Buckminster, Boston, Mass.

William B. Durant, Jr., '10, is with the New York, New Haven and Hartford R.R. at New Haven, Conn.

H. B. Garland, '10, is teaching mathematics at Phillips Academy, Andover, Mass.

William E. Hearn, '10, is designer with the Van Norden Sheet Metal Company, Roxbury, Mass. Address: 19 Alaska Street, Roxbury, Mass.

E. N. Hutchins, '08, is an Assistant Engineer under the Board of Water Supply, New York City. Address: Room 725, 165 Broadway, New York City.

C. W. Lewis, '07, is at present Civil and Hydraulic Engineer on the staff of C. W. Humphrey, of Chicago. Address: Care of C. W. Humphrey, 618 The Rookery, Chicago, Ill.

George W. Lewis, '10, is a sub-foreman with the Hugh Nawn Contracting Company, Boston. Address: 103 Cushing Street, Waltham, Mass.

H. L. Lincoln, '06, has left the Power and Mining Department of the General Electric Company, and is in the Engineering Division of the Contract Department of the Commonwealth Edison Company, Chicago, Ill. Address: 4647 Winthrop Avenue, Chicago, Ill.

John F. Manning, '03, is in the employ of the Seoul Mining Company, Pyeng Yang, Korea.

Carl F. Massey, '10, will be at the Kuahivi Ranch, Cashmere, Wash., this winter.

Edwin W. Mills, '02. Address changed from Chicksan, Korea, to Care of Korea Syndicat, Snesen, Korea.

Hugh Nawn, '10, is with the Hugh Nawn Contracting Company, Boston, as superintendent. Address: 43 Brunswick Street, Roxbury, Mass.

Q. A. Shaw, '91, is President of the Calumet and Hecla Mining Company. Address: 12 Ashburton Place, Boston, Mass.

Edgar L. Smith, '05, is in the branch office of Ford, Bacon and Davis of New York at New Orleans. Address: Liverpool and London and Globe Building, New Orleans.

William A. Spencer, '06, is supervisor of traffic for the Michigan State Telephone Company, with headquarters at Detroit. Permanent address: 2 Craigie Street, Cambridge, Mass.

George F. Williams, '09, is with the Dennison Manufacturing Company, South Framingham, Mass. Address: 4 Beech Street, South Framingham, Mass.

Sidney Withington, '06, is with the New York, New Haven and Hartford R.R. Address: Care of New York, New Haven and Hartford R.R., New Haven, Conn., or 35 Bay State Road, Boston, Mass.

Edward S. Wolston, '10, is engineer with the U. S. Geological Survey at Canton, Me.

MISCELLANEOUS NOTES

APPOINTMENTS

Meeting of June 13, 1910:
  Instructors for one year from September 1, 1910:—
    Elton James Moulton, Ph.B. (*Mathematics*).
    David Locke Webster (*Mathematics*).
  Assistants for one year from September 1, 1910:—
    Cornelius Beard (*Mechanical Engineering*).
    John Williams Davis, M.E. (*Electrical Engineering*).
    Leonard Allison Doggett (*Electrical Engineering*).
    Edward Arthur Healey (*Electrical Engineering*).
    Brackett Kirkwood Thorogood (*Mechanical Drawing*).
    Marl Ruskin Wolford (*Mechanical Engineering*).
  Austin Scholarships in Architecture:—
    Godfrey Kern Downer, 4c., Monongahela, Pa.
    Sidney Fiske Kimball, 1G.S., Dorchester, Mass.
      A.B. 1909; Assistant in Fine Arts, 1909-10.

Meeting of October 10, 1910:—
  Members of Administrative Boards for 1910-11:—
    For University Extension:—
      Hector James Hughes, A.B., S.B.
    For the Graduate School of Arts and Sciences:—
      William M. Davis, M.E., S.D., Ph.D.
      Benjamin Osgood Pierce, Ph.D.
      Gregory Paul Baxter, Ph.D.
    For the Graduate School of Applied Science:—
      Arthur Edwin Kennelly, Sc.D., A.M.
      Henry Lloyd Smyth, A.B., C.E.
      Frank Lowell Kennedy, A.B., S.B.
      Edward Vermilye Huntington, Ph.D.
      Hector James Hughes, A.B., S.B.
  Assistant for one year from September 1, 1910:—
      Warren Ordway (*Mechanical Engineering*).

Among *recent publications* by members of the staff were:—

"The Elementary Theory of the Gyroscope in the Brennan Monorail Car," by E. V. Huntington. *Engineering News,* July 21, 1910.

"A Magnetic Holder for the Microscopical Examination of Metals," by Albert Sauveur. *The Iron Age,* June 23, 1910.

"Vector Power in Alternating-Current Circuits," by A. E. Kennelly. *Proceedings of the American Institute of Electrical Engineers,* June, 1910.

"Graphic Representations of the Linear Electrostatic Capacity Between Equal Parallel Wires," by A. E. Kennelly. *Electrical World,* October 27, 1910.

"The Physiological Tolerance of Alternating-Current Strengths up to Frequencies of 100,000 Cycles per Second," by A. E. Kennelly and E. F. W. Alexanderson. *Electrical World,* July 21, 1910.

"The Magnitude of an Error which Sometimes Affects the Results of Magnetic Tests upon Iron and Steel Rings," by B. O. Peirce. *Proceedings of the American Academy of Arts and Sciences,* September, 1910.

"Initiative and Referendum: An Effective Ally of Representative Government," by L. J. Johnson, has been published in a fourth edition by the Massachusetts District Legislative League.

"A New Applied Science, perhaps to be called Civic Engineering," by L. J. Johnson. *Engineering News,* November 25, 1910.

"Inexpensive English Homes, with Suggestions," by H. A. Frost.

The "Steam Tables and Diagrams" published last year by L. S. Marks and W. M. Davis have now gone into a second edition. The table has been very generally accepted as the standard throughout the country.

PERSONAL NOTES

The staff of the Department of Electrical Engineering is actively interested in the work of the American Institute of Electrical Engineers, not only rendering service on many of the important committees, but also attending the monthly meetings in New York City and contributing to the discussion of the papers there presented.

Professor Adams, a past-chairman of the Boston Branch of the A. I. E. E., is chairman of the Standards Committee and a member of the Industrial Power and of the Edison Medal Committees. As consulting engineer of the American Tool & Machine Company, he has completed several new designs for induction motors and for centrifugal machinery to be used in

sugar refining. As consulting engineer for the Warner Sugar Refining Company, of New York, he is at present engaged in the preparation of plans for the enlargement of their refinery power plant.

Professor Clifford, a past-chairman of the Boston Branch of the A. I. E. E., is at present serving on the Board of Managers and is a member of the Law Committee and of the Edison Medal and Editing Committees. Professor Clifford, as consulting engineer of the General Electric Company, spent a month during the summer at the works at Schenectady, in connection with certain development work on high tension switches. As consulting engineer for the city, he has been considering the general question of street lighting for the City of Providence, R. I. He addressed the Mathematical Club of Harvard University at its opening meeting of the year on "The Uses of Mathematics in Engineering."

Professor Clifford has been invited by the McGraw-Hill Publishing Company to serve as chairman of a Committee on Electrical Engineering Texts for use in the universities and technical schools of the United States. The committee is made up of engineers, many of whom are engaged in the work of instruction in electrical engineering.

Professor Kennelly, a past-president of the A. I. E. E., is President of the United States National Committee of the International Electro-technical Commission and Secretary of the Standards Committee. During the past summer he visited Brussels as the American representative of the Commission.

Professor Swain is in charge of the examination of the assets and liabilities of the New York, New Haven and Hartford Railroad, under the direction of the Joint Board constituted by the Legislature at its last session. The work involves the physical valuation of the road, including its subsidiary trolley and steamship properties. Professor Swain was consulting engineer on the replacement of the old chain suspension bridge across the Merrimack River near Newburyport, last year. The new structure, a steel cable suspension bridge with reinforced concrete towers and steel stiffening trusses, was designed by him.

Professor L. J. Johnson delivered a lecture on "The Design and Construction of the Harvard Stadium" before the Brown University Engineering Society, November 1.

Professor H. L. Warren will give a course of five lectures before the Brooklyn Institute of Arts and Sciences on the architecture of the home.

Professor William M. Davis has been elected a corresponding member of the Royal Prussian Akademie der Wissenschaften, at Berlin.

Professor Sauveur presented an illustrated paper on "Apparatus for the Microscopical Examination of Metals" at the meeting of the American Society for Testing Materials, held at Atlantic City, N. J., in June, 1910.

Professor A. Lawrence Rotch gave an illustrated lecture on "The Aerial Ocean and Its Navigation" on June 3 before the Annual Convention of Pennsylvania Engineers, in Harrisburg.

Mr. J. R. Nichols was with the Pennsylvania Steel Company at Steelton, Pa., during the summer.

ITEMS OF INTEREST

There are twenty graduate students in the Department of Architecture this year, as compared with six last year. The figures in both cases include the two men in Europe on the Department scholarship.

A six-ton ammonia compression refrigerator plant is now being installed in the laboratory. It is to be fitted up for investigations under the direction of Professor Marks.

Current numbers and bound volumes of "Die Turbine," "Ice and Refrigeration," and "Zeitschrift für die gesamte Kälte Industrie" have been added to the library.

Room 103, Pierce Hall, is being fitted up as an electrical standardizing laboratory. Several new machines have been added to the Dynamo Laboratory. The number of portable measuring instruments has been largely increased. Room 106 has been equipped for electrical instrument work.

ADDITIONS AND CHANGES IN COURSES OF STUDY

A new course in Electrical Engineering for graduate students in Civil and Mechanical Engineering is being given for the first time in 1910-11. Professor Clifford is in charge of the work.

A complete re-numbering of the courses in the Electrical Department will take place this year.

JANUARY, 1911.

THE OFFICIAL ORGAN OF THE ASSOCIATION OF HARVARD ENGINEERS

HARVARD ENGINEERING JOURNAL

A QUARTERLY
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VOL. IX. TABLE OF CONTENTS No. 4

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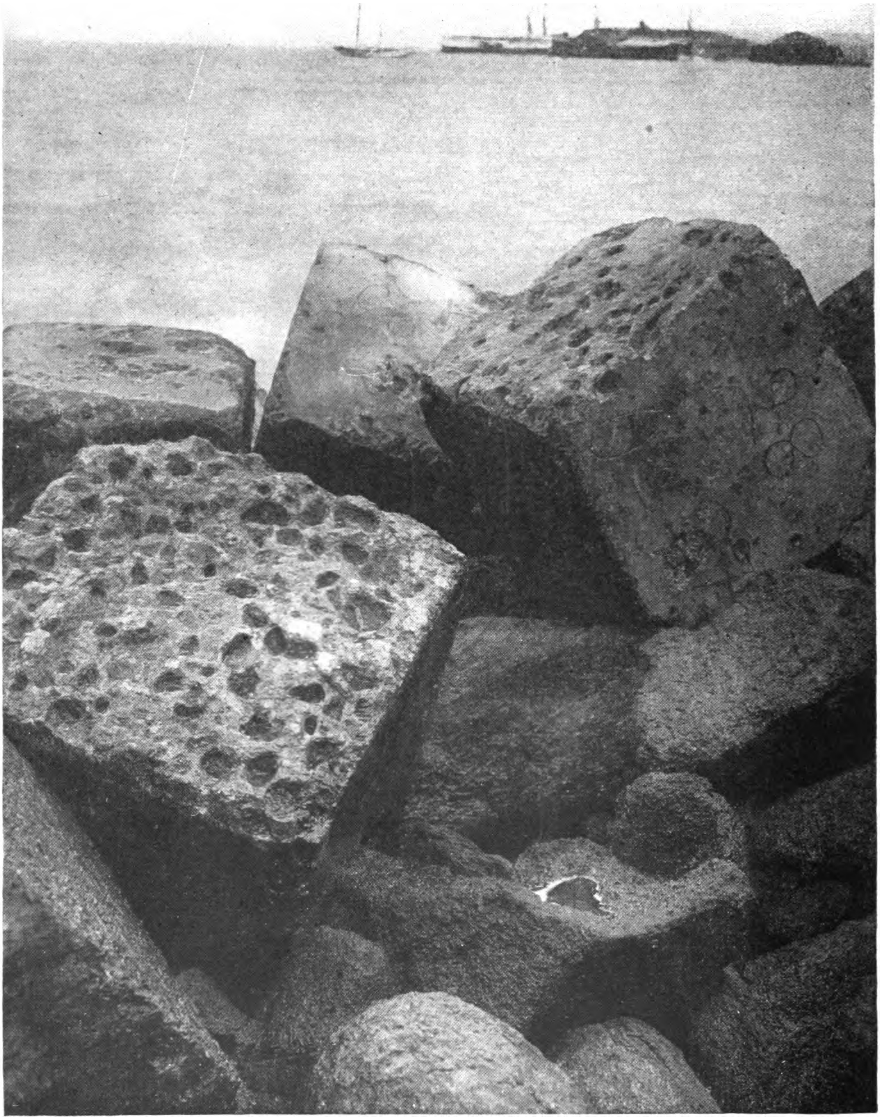

Frontispiece. *See page 198.*

PLATE NO. 2.

HARVARD
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THE OFFICIAL ORGAN OF THE ASSOCIATION OF HARVARD ENGINEERS

VOL. IX | JANUARY, 1911 | NO. 4

ACTION OF SEA WATER ON CONCRETE BLOCKS, CRISTOBAL, CANAL ZONE

CALEB MILLS SAVILLE,* '89, MEM. AM. SOC. C. E.

In view of the more and more extended use of concrete in the construction of docks, canal locks, and other structures more or less exposed to the action of sea water, any information bearing thereon is of value. Especially is this the case if the data has been collected from structures that have actually been exposed to working conditions.

The notes presented herewith refer to a rivetment of large concrete blocks placed by the French in 1886 on the northerly shore of Cristobal Point in the Canal Zone as a protection against the waves. Due to the prevailing direction of the winds from the north and northeast during the dry season (January to April), particularly severe storms known locally as "Northers," the shore is especially exposed to wave action. These storms are very severe, the waves at times breaking clear across the street against the houses on the opposite side, and the bay is in such condition that ships are obliged to seek anchorage elsewhere. From the above, therefore, it appears that concrete blocks which have withstood this action for 24 years present features in material and composition that can be relied on for permanent work in like cases of exposure. The range of tides at Cristobal is very small, the maximum being only 1.97 feet, and at times there is only one tide in 24 hours. The average sea temperature is 81.7° Fahr. and the specific gravity of the water has been found to be 1.023.

* Engineer in Charge of Third Division, Office of Chief Engineer, Isthmian Canal Commission.

The following notes and the accompanying photographs are presented at their face value, no attempt being made to analyze them and only a few remarks being made to call attention to salient features.

Appended are the following: —

1 — Translation of the cement specifications of the first Panama Canal Co.

2 — Analyses: Chemical (a) Portland cement.
(b) Panama Beach sand.
(c) Mortar from blocks.
Mechanical (d) Panama Beach sand.

3 — Translation of the contract and specifications under which the concrete blocks were constructed.

The investigations were made by direction of Col. Geo. W. Goethals, Corps of Engineers, U. S. A., Chairman and Chief Engineer of the Isthmian Canal Commission, and by his courtesy the results are permitted to be published.

Plate No. 1 shows the general location of the blocks and the manner in which they were placed on the shore to protect it from the waves. The blocks are one cubic meter in volume. They were made from imported cement, sand from the shore of the Pacific Ocean near Panama, and stone from the quarry near Bohio (see Appendix 3), from whence came also much of the stone that was used in bridge abutments and culverts on the Panama Railroad location.

Plates Nos. 2 and 3 show the blocks in greater detail, and attention is particularly called to the figures and other marks which were scratched on the soft cement coating when the cubes were made. The quality of the materials and the thoroughness of mixing and placing can be judged from the sharp edges of the blocks which for almost a quarter of a century have withstood the pounding and grinding action of the waves, driven directly upon them by the prevailing winds of the Caribbean Sea.

Plate No. 4 gives an idea of the wave action to which this rivetment has been exposed, and yet the day on which these photographs were taken was one of comparative calm, even for the dry season.

Exact knowledge of the method of construction is not at hand, but it appears from examination that strong forms of a cubic meter size were made, and the concrete rammed in. When

full, the exposed surfaces were evidently skim-coated with neat cement. Most of the blocks show clean-cut markings and the coating is hard, firm and resistant.

In all of the photographs the rounded and irregular masses that show under and around the concrete blocks are large rocks more or less worn by the action of the surf. The characteristics of these rocks appear similar to those of the rock fragments of the concrete. It is, therefore, reasonable to suppose that these rocks also were brought from the Bohio quarries for use in the

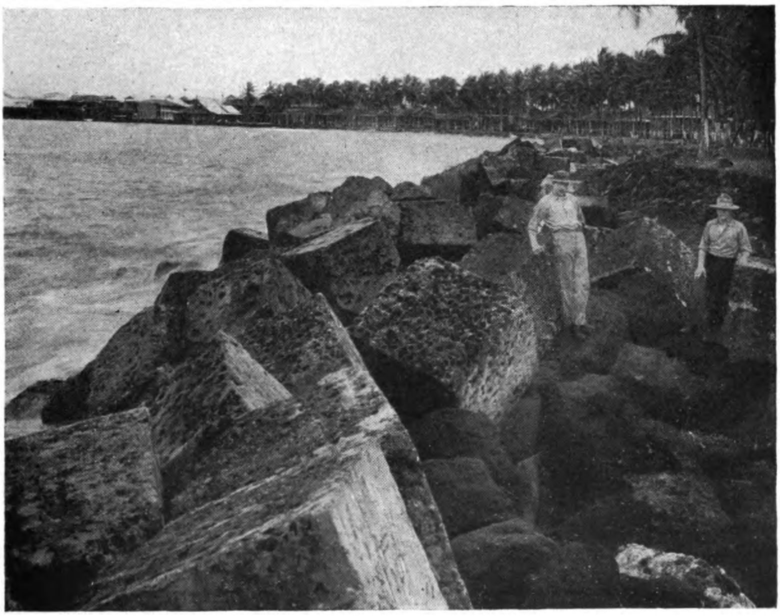


PLATE No. 1.

bulk of the rivetment, the exposed face being protected by the more durable concrete blocks.

A close examination of these blocks shows that the worm-eaten appearance noted in the photographs is not due primarily to the action of the sea-water, but is caused by insufficient ramming near the sides of the forms. In support of this, the clauses in the specifications are considered, noting the consistency required for this concrete and the difficulty experienced, even today, in getting suitably compacted concrete near the sides of forms

without spading or special tools. That such tools were not used here is very evident from inspection of the blocks. The concrete in the blocks has not softened or disintegrated, is hard and firm on its surface, and there is no evidence of decay that could be ascribed to chemical action of the sea-water on the cement.

A fragment from a block of this concrete was taken at random, and the following calculations made of specific gravities of the materials and percentages used:

Specific Gravities and Weights.

	CONCRETE	MORTAR	STONE
Weight of mass taken for study	94.75 lbs.	3.82 grams	24.97 grams.
Displacement in water	0.75 c. f.	2 65 c. c.	10.00 c. c.
Specific gravity	2 02	1.44	2 50
Weight per cubic foot	1.26 lbs.	93.50 lbs.	156 00 lbs.

Let Vm = volume of mortar in concrete block.
Let Vs = volume of stone in concrete block.
Then Vm + Vs = 0.752 cu. ft.
and 1.44 Vm + 2.50 Vs = 0.752 x 2.02.
Solving simultaneously, Vm = 0.34 cu. ft.
Vs = 0.41 cu. ft.
Weight of mortar in mass = 0.34 x 62.4 x 1.44 = 30.6 lbs.
Weight of stone in mass = 0.41 x 62.4 x 2.50 = 64.1 lbs.
Total weight of concrete in mass = 94.75 lbs.

Therefore

Volume of stone in concrete = 0.41 cu. ft. = 68% volume of concrete.

Volume of mortar in concrete = 0.34 cu. ft = 32% of volume of concrete.

CALCULATION OF VOIDS — TWO EXPERIMENTS.

First Experiment: A section of the concrete was immersed in water.

Displacement of section of concrete	16.4 lbs.
Displacement of section of concrete after soaking 3 hours	15.5 lbs.
Loss = Voids in Concrete =	0.9 lbs. =

5.5% of volume of concrete.

Second Experiment: A fragment of the mortar alone was used.

Displacement of fragment of mortar	2.65	Cu. cm.
Displacement of fragment of mortar after soaking ½ hour	2.05	Cu. cm.
Loss = Voids in mortar,	.60	Cu. cm.

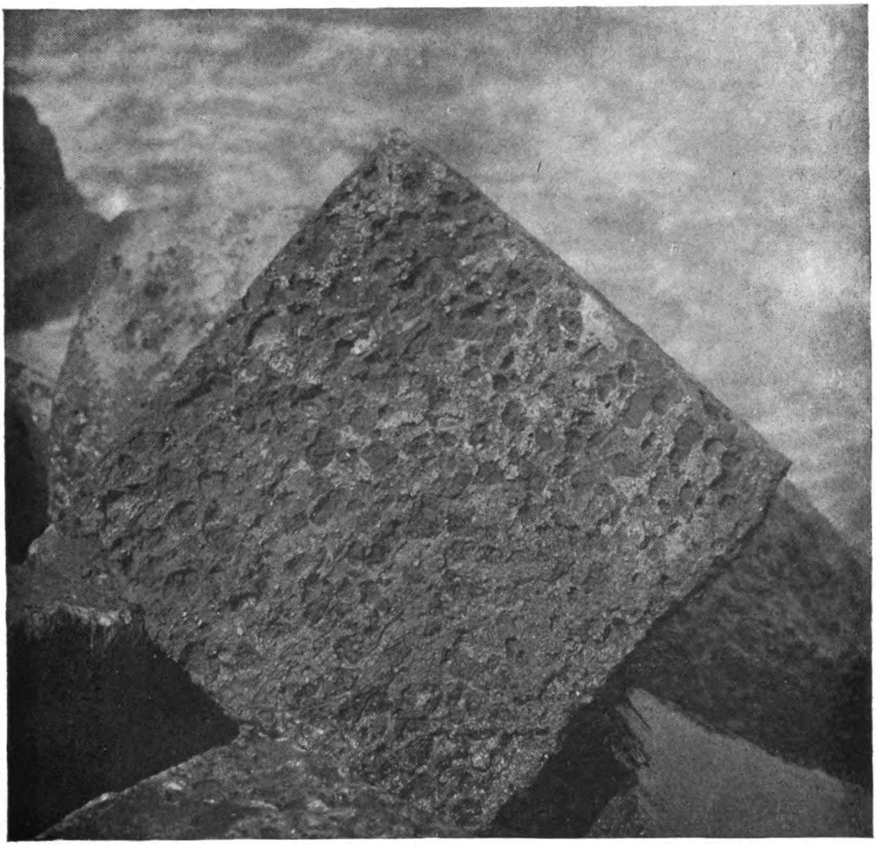


PLATE No. 3.

Therefore $\frac{0.60}{2.65}$ or 22.6% of mortar is voids. The mortar being 32% of the mass of concrete, the percentage of voids in the concrete is .226 x .32 or 7.2% of the volume.

By first experiment voids = 5.5% of volume of concrete.

By second experiment voids = 7.2% of volume of mortar.

Of the 0.34 cu. ft. of mortar and voids in the concrete block, 22.6% is voids. Therefore, the actual volume of mortar, not counting the voids, is 77.4% of the volume of mortar and voids $= .774 \times 0.34 = 0.27$ cu. ft., the specific gravity of which will be $\frac{30.06}{.27 \times 62.4} = 1.81$.

APPENDIX I.

SPECIFICATIONS OF THE FIRST PANAMA CANAL COMPANY FOR THE FURNISHING OF CEMENT

(Translation)

The Portland Cement was to be exclusively of the following brands:

1 Societe des Ciments Francais et des Portland.

2 Cie. Nouvelle des Ciments Portland du Boulonnais.

Examinations were made at the mill before shipping, and others on the Isthmus.

A. *Verifications or tests to be made before shipping.*

1. Dryness: 4 grammes heated white red in a cup of platinum must not decrease in weight more than 300 milligrammes. Condemned if so.
2. Specific weight of cement.
3. Chemical composition.
4. Time of setting.
5. Absence of cracks after setting.
6. Strength of bricks of pure cement.
7. Strength of bricks of cement and standard sand.

Specific weight:

The cement must be sifted through a sieve of 5000 meshes per square centimeter into a cubical measure of 1 liter capacity; over said measure, an inclined plane of 45 degrees, made of zinc sheet 50 centimeters long, the inferior edge of which must be 1 centimeter above top of measure. Cement must be thrown carefully with a spoon on the upper end of the incline until the measure is over-filled. The excess of cement must then be taken off by a straight blade drawn vertically across the top of the measure.

During the operation, no jerk or blow or any agitation should take place. This operation must be repeated five times and the average will be the weight of 1 liter of cement. The minimum obligatory weight *not compressed* shall be determined in the following manner: At the mill a quantity of burnt material shall be taken from amongst the heaviest — well burnt, with a black or bluish-black color. This material shall be ground so as to give a waste of 20 to 25% when screened through a sieve of 5000 meshes per square centimeter. The screened cement will give the standard weight of

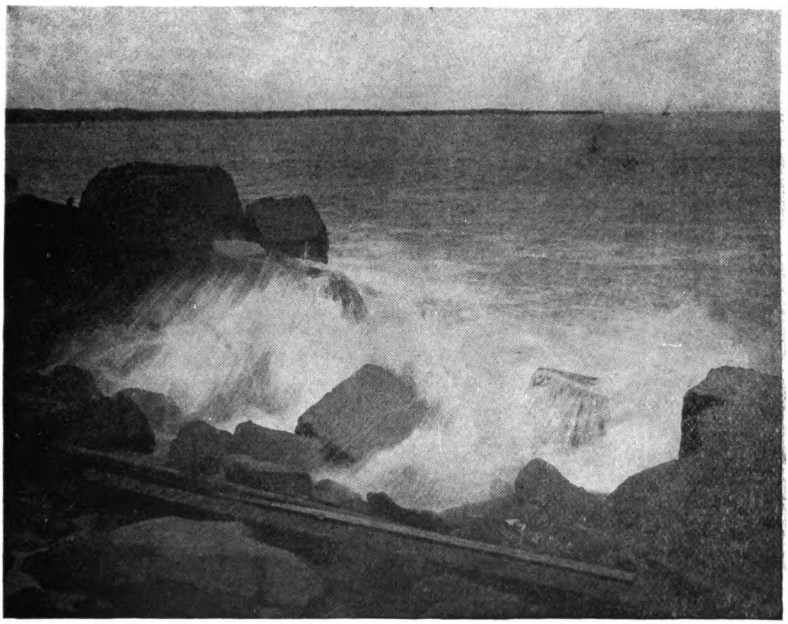


PLATE NO. 4.

one liter by the above-mentioned method. The standard weight decreased by 100 grammes shall be the minimum obligatory weight.

Chemical Composition.

Cement will be condemned when analysis shows more than 1% sulphuric acid or any trace of sulphides; more than 4% iron oxide or when total weight of silica plus weight of alumina is less than 44% of weight of lime.

Tests with pure cement.

A quantity of cement shall be mixed with sea water, and its temperature kept as low as 15 to 18 degrees centigrade.

Proportion of water: Take 900 grammes of cement and pour the water in at one time. Mixing shall be done on a marble plate with a trowel during five minutes, counting from the time of pouring water. The quantity of water will be considered as good when:

1. Consistency of paste does not change if mixing is prolonged for three minutes beyond the first five minutes.

2. When a small quantity of paste taken up with the trowel and dropped from a height of 50 centimeters on the marble plate does not leave on the trowel any attached particles of paste and shows, after fall, a round form without any cracks.

3. A small quantity of paste, when taken up with the hand and turned over with slight jerks, shall take a round form without sticking to the hand. The water shall show on the surface of the ball and when it falls on the marble plate from a height of 50 centimeters shall take a slightly depressed round form without any cracks.

4. The proportion of water shall be such that a smaller quantity will give a dry paste which shows cracks when thrown on the plate, and that a slightly larger quantity (1 to 2% of cement weight) will be sufficient to change the appearance of the paste, giving it a muddy consistency, and causing it to adhere to the hand or trowel so as to prevent the making of a ball with the hand as above. This last change of the character of the paste — from plastic to mucky consistency — being the most defined, the mixing shall be made first with a small quantity of water giving a very dry paste. The operation shall be repeated with a fresh quantity of 900 grammes of cement, increasing every time by 20 cubic centimeters the quantity of water until the operation gives a paste of firm and plastic consistency, and the following mixing gives a muddy paste. A mixing with only 10 cubic centimeters of water less than in the mixing which gives the muddy paste, shall be made.

The highest proportion of water that has given a plastic and not a mucky paste shall be adopted as standard proportion.

Time of setting:

To determine the beginning of setting and the time of setting, a quantity of 900 grammes of cement shall be taken and mixed

for five minutes with the above found standard quantity of water on a marble plate, the entire quantity of watei being poured at one time on the cement. With this paste, a cylindrical box 4 centimeters high and 8 centimeters in diameter shall be filled, the box being tapped lightly to settle the paste. The water that shows on the surface shall be allowed to remain. By means of a thread passing over a pulley, a prismatic needle weighing 300 grammes and with a section equal to 1 square millimeter shall be suspended over the box. The time of beginning of setting shall be taken as the moment when the needle can no longer be passed through the whole mass of cement. The setting shall be considered as terminated when the surface of the cement will support the needle, that is, when the needle cannot penetrate appreciably. If the cement commences to set before an interval of thirty minutes, or fails to begin within three hours, it shall be condemned. The cement shall also be condemned if the setting is not completed before the expiration of twelve hours.

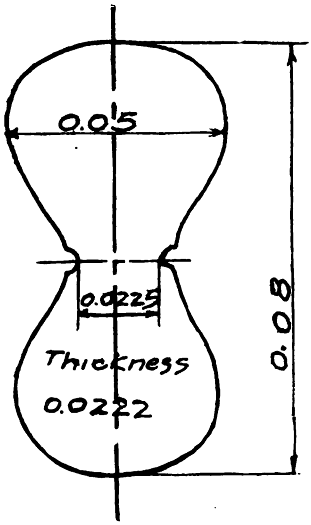
The time shall be computed from the moment that the water has been poured on the dry cement powder. The temperature shall be kept as near as possible to 15 to 18 degrees centigrade.

Absence of cracks after setting:

Immediately after filling the metallic box with the above-mentioned paste, the remainder of the paste shall be put on glass plates in cakes of from 8 to 10 centimeters in diameter and a thickness of 2 centimeters in the center decreasing to nothing at the edges. These cakes shall be kept in a moistened atmosphere, away from drafts and from the action of the sun, for a time as long as the above-determined setting time. The cakes on their glass plates shall then be immersed in a bucket of sea water with a temperature as near as possible to 15 to 18 degrees centigrade. If before being taken from the water, any cracks are shown in any one of the cakes, the cement shall be condemned.

Strength of bricks made with pure cement:

For these tests a mortar of pure cement shall be made by mixing 900 grammes of cement with the standard proportion of sea water previously determined. Said mixture shall give enough mortar to make six bricks. Each test shall include 18 bricks, consequently the above mixture must be made three times.



Three bricks shall be made with a form placed on a plate of marble or of polished metal. Six forms shall be filled at a time, the mortar being pressed down with the trowel and the sides of the form slightly tapped until a little water shows on the surface of the mortar. As soon as the cement is hard enough, a sharp knife held vertically with the edge a little forward shall be passed over the surface of the form, without exerting any compression so as to take away the excess of mortar.

After complete setting, the forms shall be taken away and the bricks left on the marble plate. For 24 hours after the mixing of the cement, the bricks shall be left on the plate in a moistened atmosphere, sheltered from drafts and the sun, with a temperature as near as possible to 15 to 18 degrees centigrade. After 24 hours the bricks shall be immersed in a bucket filled with sea water, changed every week, kept as near as possible to 15 to 18 degrees, centigrade, and 18 bricks shall be made as above for each kind of cement, six of same to be tested after *7 days,* six after *28 days,* and six after *84 days* from the time of mixing. For each series of tests, 2 bricks of each mixing shall be taken.

The bricks shall be tested for tensile strain by means of the machine with double lever, in which the increasing weight that produces the fracture is obtained by the pouring of fine lead shot into a cup suspended at the end of the second lever. Of the six tests, the three giving the highest figures will be the tensile strength of the tested samples of cement at the moment of the test.

Required strength of pure cement bricks:

The strength of pure cement bricks shall be, at the end of the seventh day, at least 20 kilogrammes per square centimeter (284 pounds per square inch). It shall be at least 35 kilogrammes per square centimeter at the end of the 28th day (498 pounds per square inch).

The strength per square centimeter after 28 days shall be at least 5 kilogrammes higher than the strength after seven days = 71 pounds per square inch. The strength per square centimeter after 84 days shall be at least 48 kilogrammes = 640 pounds per square inch. It shall be higher than the strength after 28 days. If these conditions are not fulfilled, the cement shall be condemned.

Strength of mortar with standard sand:

The mortar of this test shall be made up of one part of dry cement and three parts of dry standard sand by weight. The standard sand is made by screening sand through a sieve of 64 meshes per square centimeter or 413 per square inch, to eliminate the largest particles and through a 144 meshes per square centimeter, equals 919 per square inch, to eliminate the finest particles. This screened sand, thoroughly washed and dried, shall be the standard sand.

The quantity of sea water to incorporate with the sand and cement mixture shall be equal to 12% of the total weight of the cement and sand.

Each mixture shall be sufficient to make three bricks and a trifle more. One hundred and twenty-five grammes of cement shall be mixed with 375 grammes of sand. Each test shall be of 18 bricks, consequently the mixing shall be made six times under the same conditions. The forms of the bricks shall be the same as for the pure cement tests, and the mixture shall be made in the following manner:

The forms, previously cleansed and wetted, shall be placed on plates of marble or polished metal, 125 grammes of cement and 375 of sand shall be mixed in a cup with a spatula. The required quantity of water, 60 cubic centimeters, shall then be added at one time and the whole mixed for five minutes from the time the water has been added. The mortar shall then be placed at one time into the forms in quantity a little greater than the contents of the form. By means of a little hammer weighing about 200 grammes, the mortar shall be tamped in the form, commencing in the center, until the mortar becomes slightly elastic and covered with a little water. The excess of mortar shall then be removed with a sharp knife.

When the mortar is hard enough, the forms shall be removed and the bricks left on their plates, for 24 hours from the moment

when the mixing has been commenced in a moistened atmosphere, away from air drafts and sun with a temperature as near as possible to 15 to 18 degrees centigrade or 59 to 65 degrees, Fahrenheit.

For each kind or invoice of cement to be tested, 18 bricks of standard cement and sand shall be made under the above-mentioned conditions, of which 6 are to be tested after 7 days, 6 after 28 days and 6 after 84 days from the time of mixing the mortar. For each series of tests, one brick of each mixing shall be taken.

Of the six obtained results of tests, the three highest shall be taken, the average of these three highest figures will be the admitted figure of the strength of tested mortar at the time of test. The strength of the mortar after the 7th day shall be at least 8 kilogrammes per square centimeter, equals 114 pounds per square inch, after 28 days. It shall be at least 2 kilogrammes per square centimeter, equals 28 pounds per square inch, higher after 28 days than after 7 days.

The strength per square centimeter after 84 days shall be at least 18 kilogrammes per square centimeter, equals 256 pounds per square inch and shall always exceed the strength of 28 days.

B. Verifications made just before shipment.

At the moment of shipping, the Company can open a certain number of barrels and verify the state of the cement. If it appears to be not perfectly pulverized in all its parts, the cement shall be refused in spite of all the good results the previous tests may have given.

The cement shall be shipped in casks, reinforced by two iron rings at each end, and lined inside with strong ordinary paper, and with a tar paper and sealed with lead, so that their origin may not be doubtful when reaching the Isthmus. Each cask shall bear a label showing the gross weight and the net weight.

C. Verification on the Isthmus:

Admittance in the stores shall be prohibited to all the barrels that are damaged upon arrival. The same prohibition shall be enforced to any suspicious cask whose contents is not frankly pulverulent in all its parts.

The Company has the right to throw into the sea all the damaged barrels.

D. Laboratory Verifications:

In addition to the above-mentioned prescriptions, the Agent of the Company, at any time he deems advisable, shall make laboratory tests with a view of finding out if the cement supplied by the contractor, keeps up its qualities shown in France, with regard to its hygrometrical state, setting properties and strength.

These verifications shall be made with the same care as those made in France, and under the special conditions that the Company's agent may think advisable to prescribe, taking into account the temperature and hygrometric state of the atmosphere.

The cements not giving satisfactory results shall be condemned and taken out of the stores, and out of the construction yards. The approval thus given by the Company's agent shall not impair the responsibility of the contractor as regards to the quality of mortars and masonry until the expiration of the time of guaranty.

APPENDIX 2.

a. Composition of Ciment Portland Boulonnais.

Silicious Sand	1.05
Combined Silica	24.10
Alumina	7.20
Peroxyde of Iron	3.35
Lime	59.40
Magnesia	0.95
Sulphuric Acid	0.55
Loss by Ignition	2.80
	99.40

b. Quantitative Chemical Analysis of Sample of Sand from Panama Beach in the Vicinity of Punta Prieta. (Made at Board of Health Laboratory, Ancon, February, 1909.)

Chemical No. 244:

Moisture (after drying sufficiently to powder sample)	0.46%
Silica	23.28
Alumina + Ferric Oxide	6.93
Calcium Carbonate	65.86
Magnesium Carbonate	2.12
Sodium Oxide	0.99

Potassium Oxide	0.31
Sulphur Trioxide	0.30
Phosphoric Acid (P2 05)	0.85
	101.10%
Loss upon ignition	29.26%

The calcium and magnesium were calculated as carbonates, since the loss upon ignition consisted principally of carbon dioxide and some organic matter.

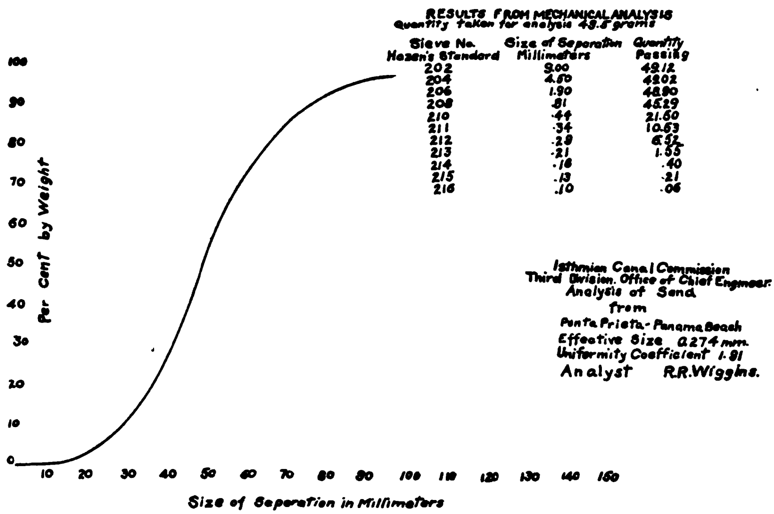


PLATE No. 5.

c. Chemical Analysis of Sample of Mortar from Concrete Blocks, Cristobal. (Made at Board of Health Laboratory, Ancon, February, 1909.)

Chemical No. 243:

Moisture (105° C.)	5.06%
Insoluble Silicious Matter	10.66
Alumina + Ferric Oxide	4.69
Calcium Carbonate	81.61
Magnesium Carbonate	1.17
	103.19%

Separation of residue insoluble in dilute hydrochloric acid by repeated sedimentation in distilled water:

Sand	1.70
Clayey Matter	2.62
	4.32%

Sample labeled "Mortar from Concrete Blocks, Cristobal," consisting of a very light gray, quite porous, cementing substance, containing an abundance of fragments of small shells, and in which is embedded angular fragments of a rock resembling some-

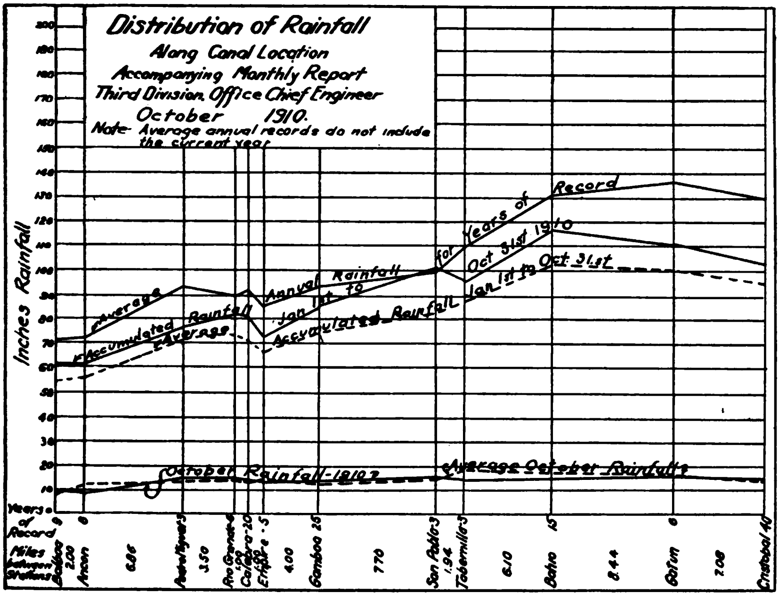


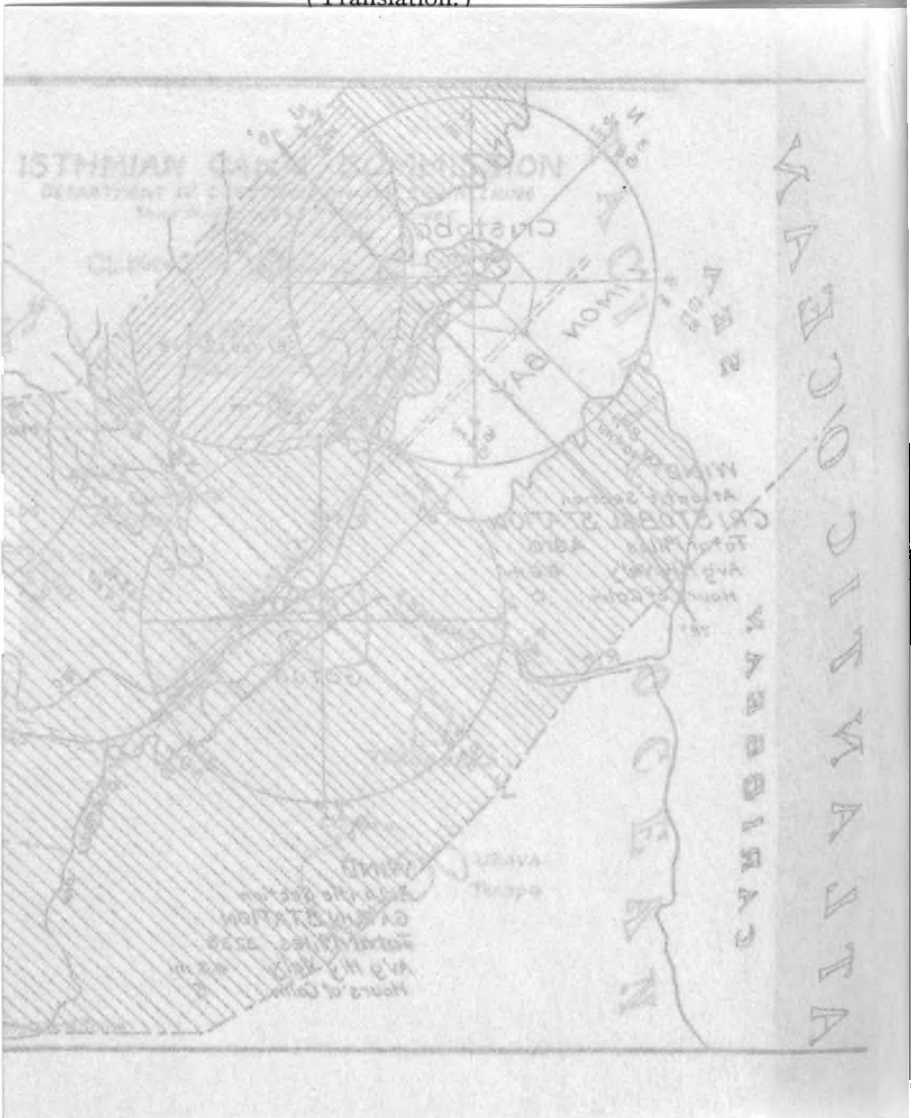
PLATE No. 6.

what that which occurs in the cliff near the railroad station at Bohio, ranging in size from a pea to that of a goose-egg.

A comparison of the amount of insoluble silicious matter found in the analysis and the sand and clayey matter found by sedimentation in this sample would seem to show considerable cementing material other than that derived directly from lime mortar. This point is further strengthened when we take into account that a considerable portion of the calcium comes from the shells present, which could not be separated like most of the incorporated rock material.

APPENDIX 3.

(Translation.)



mixing continued with an iron hoe as long as necessary to completely incorporate the stone in the mortar so that every part of said stone shall be covered with mortar.

The mixing of concrete shall be made without the addition of water. The crushed stone, however, shall be watered carefully in the stone heaps, and always at least one hour before using.

The concrete shall be placed immediately after mixing. The drier concrete shall be absolutely refused.

Art. IV. The concrete shall be dumped into forms in layers 0.25 meter thick, and compressed so as to form a compact mass. Excessive ramming shall always be carefully avoided so as not to soften the mortar too much.

The portions of concrete already laid shall be stripped, scraped, and coated with fresh mortar before placing upon it new concrete.

(Translation.)

Contract awarded to Brochet, May 27, 1884, for 200 masonry blocks to be placed in the sea water at Fox River.

Sizes of blocks: 100 of 2 x 3 x 4 meters (24 cubic meters).
50 of 2.25 x 3 x 3.50 meters (23.625 meters).
50 of 2.75 x 3 x 2.80 meters (23.1 cu. meters).
Cost: $7.00 Columbian silver per cubic meter.

TESTS: 1. Briquettes, made of 6 kilogrammes of cement for 10 liters of sand, immersed for at most 10 hours in sea-water shall support, without any depression, a square needle of 0.0015 meter loaded with 1,400 grammes.

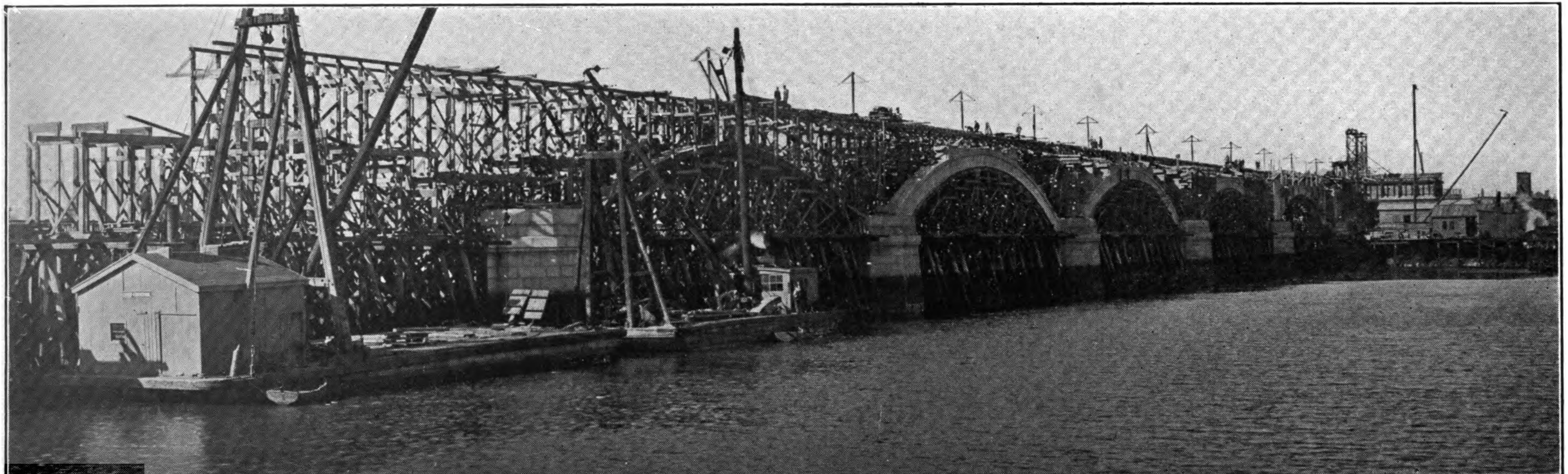
2. Briquettes of 0.20 x 0.10 x 0.04 meters, immersed for 120 hours in sea-water, shall be shaped so as to present on their middle a square section of 0.04 x 0.04 meters and stand a stress of 4 kilogrammes per square centimeter.

Stone from Kenny's Bluff (except the white bed forming the upper portion of the quarry), or from Bohio Soldado.

Sand shall be used only after at least 8 days' exposure on the yard.

Cement mortar for the blocks shall be composed of one part of cement and three of sand, and that for the facings and joints of one part of cement for two of sand. Mortar to be made under a roof, mixed dry on a wooden floor, watered, and then loaded into a mixer. When mixed, the mortar shall be tough enough to form a ball in the hand. A cylinder of 0.015 meter diameter weighing 250 grams falling from a height of 0.10 meter shall not enter into the mortar more than 0.02 meter. The stone blocks, 10 minutes before using, shall be watered with plenty of water.

NOTE: More specifications of the manner of making masonry of the blocks have been omitted in the translation.



(*Courtesy of the Engineering Record.*) FIG. 1.

GENERAL VIEW OF THE CAMBRIDGE END OF THE CHARLES RIVER BRIDGE OF THE BOSTON ELEVATED COMPANY UNDER CONSTRUCTION.

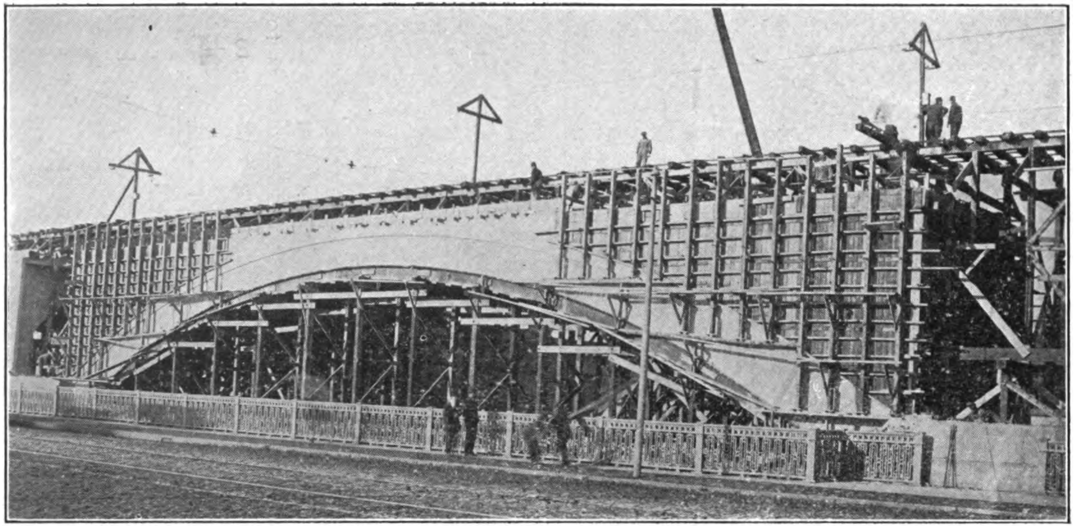
THE CHARLES RIVER BRIDGE OF THE BOSTON ELEVATED RAILWAY

J. R. WORCESTER, '82

The concrete bridge which is being built by the Boston Elevated Railway over the Charles River along the downstream side of the new dam is to form a link in the new elevated line connecting East Cambridge with the North Station in Boston. This line is to be used at first for surface cars and is to remove from the congested streets the cars which now run to the subway from Cambridge and Somerville via East Cambridge. Later, when a subway is constructed through Cambridge Street from East Cambridge to Harvard Square, the new elevated line may be altered to accommodate "elevated" trains, that is, those equipped for the third rail system and requiring elevated platforms.

This line is to be for two tracks, except that through Lowell Street in Boston a third track for storage is to be provided. From the North Station to the bridge, and from the Cambridge end of the bridge to Lechmere Square the structure will be of the steel solid-web plate girder type with a solid floor ballasted. The floor is to consist of a reinforced concrete slab over the tops of the longitudinal girders. Granolithic sidewalks are to be provided on each side under which will be ducts for feed wires, and the sidewalks are to be finished along the edges with a concrete facia surmounted with a simple iron fence.

Over the river the type of floor construction is to differ in some respects. The sidewalks with their ducts are to be used as on the rest of the lines, but the railing will be replaced with a concrete parapet, perforated with small openings. The ballast is to be dispensed with except over the piers, and a regular bridge floor of ties on steel stringers substituted. The steel stringers are to be surrounded with concrete except their top flanges, and the space between them, except for openings between the rails of each track in each panel is to be covered with a reinforced concrete slab. The chief reason for this change in style of floor is that snow can be easily disposed of through the openings, as there is no objection to letting it fall through into the water; but another incidental advantage is in the lightening



(*Courtesy of the Engineering Record.*) FIG. 2.

VIEW OF AN ARCH FROM THE CHARLES RIVER DAM, SHOWING SPANDREL WALL FORMS IN PLACE.

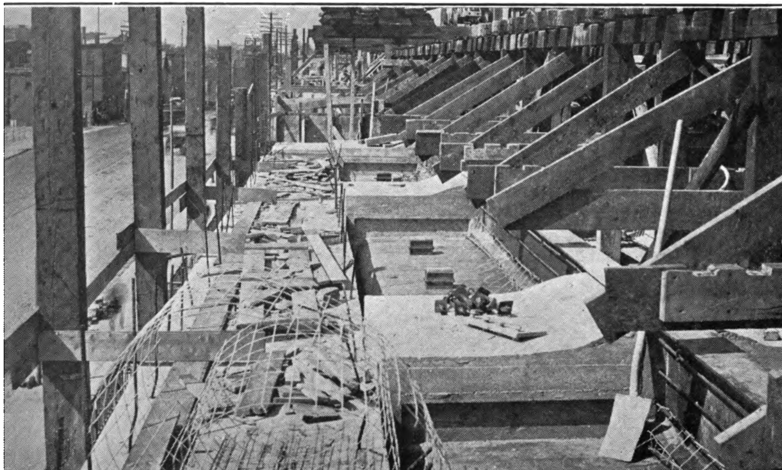
of the dead load materially. This element of lightness has had a controlling influence on the design of the bridge in all its parts. This has been necessary on account of the fact that the soil underlying the river is not as firm as could be desired, and it is probable that more or less settlement will occur, even as this bridge is designed. In fact, slight settlements have already been noted in the dam and in the piers for the bridge.

The bridge consists of ten arched spans, seven of which are over the river and three over land, a draw span over the channel and a steel girder span, surrounded with concrete, over Prison Point Street.

The profile of the river bottom at the site of the bridge, as it was before construction began, shows the depth of water at low tide to vary from nothing at the shores to about 25 feet in the middle of the river. The bottom was silt and mud to a depth of from one foot to 20 feet, the greatest depth being near the shores, and the least near the middle of the river. Under the mud was a stratum of sand and gravel of from 2 feet to 6 feet in depth, and under this, stiff blue clay down to a grade about 66 feet below low water at the deepest point. This stratum is underlaid by soft blue clay except in the eastern portion near the lock. The design for the dam called for filling to be placed over the mud, raising the bottom of the river against the north wall of the dam, that is, under the south side of the bridge, to about 3 feet below low water and sloping downward toward the north on a slope of about 2 to 1.

It was recognized at once that it was necessary for the foundations of the bridge to be carried through the fill to natural soil, and for the mud to be removed under them, and so, to save unnecessary expense, arrangements were made to construct the foundations of the bridge before the filling for the dam was begun. This necessitated carrying on the construction work while the river was being used for navigation and subject to the tidal current.

The construction of the foundations was in general carried out as follows: The first operation was to dredge the mud and silt to the depth required for the bottom of the piers. This depth varied from about 18 feet to about 33 feet below low water. Next, piles were driven over the areas of the foundations, and after them the foundations were enclosed in a wall of 6 inch hard pine sheathing, driven firmly into the bottom and of sufficient length to extend above high tide. An examination of the



(Courtesy of the Engineering Record.)

FIG. 3.

VIEW SHOWING TIMBERS FOR CARRYING STEEL STRINGERS.

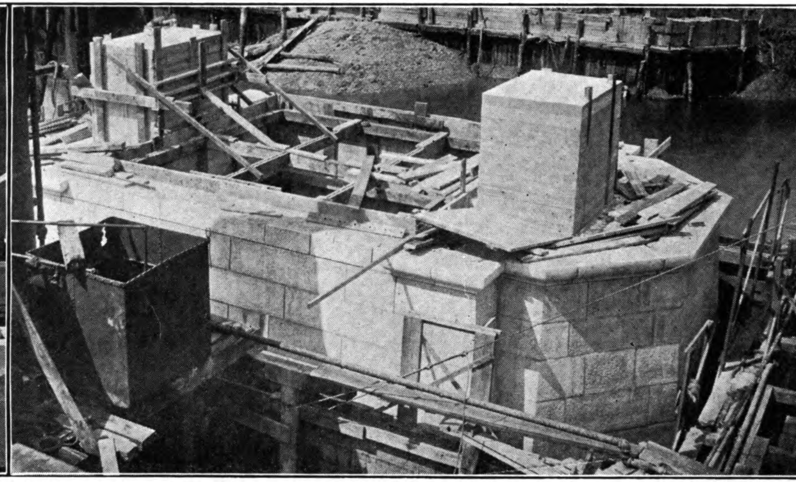


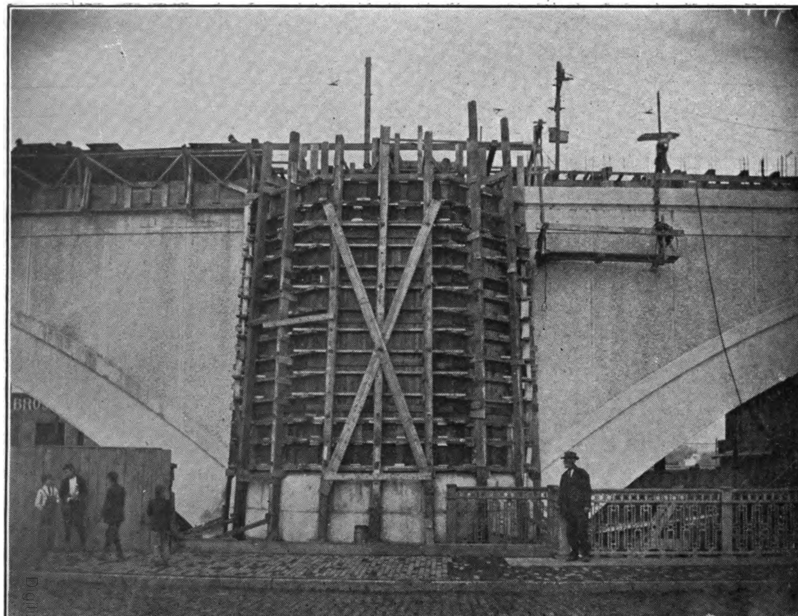
FIG. 4.

SUBSTRUCTURE OF PIER, FINISHED TO SPRING ELEVATION.

bottom after the sheeting was driven, showed that in some of the piers which were most exposed to the current the silt had come back completely covering the tops of the piles. The removal of this silt was a tedious process, but it was accomplished by means of a centrifugal sand pump, the suction of which was guided by a diver, who also used a water jet to stir up the mud in the vicinity of the suction. The power of this suction was so great that on one occasion a paving stone was drawn up and broke through the casing of the pump. After the bottoms were cleaned out, the water was allowed to come to rest and concrete was deposited by means of a bottom opening bucket, and in this way the piers were filled up to about three feet below low water. From this point the dams were pumped out and the upper layer of concrete and the balance of the masonry laid in the dry.

From a level 2 feet below low water to the level of the top of the dam, where the arches spring, the piers are hollow, to save weight and expense. They consist of concrete walls which are heavy under the main arch ribs but comparatively light in the cross walls, faced with granite. At the level of the skew backs the piers are floored over with a reinforced concrete slab. The arch seats are rectangular and made in the granite, the space between the two abutting arches on each pier having the interior portion of concrete doweled to the concrete below with heavy vertical reinforcing rods.

The arches have clear spans of 98 ft. 4 in., 122 ft. 4 in., and one of 125 ft. 4 in. Each consists of two main ribs supporting arched reinforced concrete cross floor beams which, in turn, carry the track stringers. The spandrels of the arches are, so far as the construction is concerned, practically open, for they are to be filled only with light curtain walls on each side separated from the posts supporting the cross beams by expansion joints. The ribs are 4 ft. wide and vary in depth from 6 ft. at the spring to 4 ft. 4-½ in. at the crown. The rise in each case is 19 ft. 4 in. The arches are of the two-hinge type, being provided with complete hinges of cast iron and steel with steel pins. The lower casting fits the granite seat. The hinges are surrounded with concrete, however, so that they are not visible, the radial joint in the concrete at the center of the hinge being the only mark on the surface. The arrangement of the ribs is such that a clear opening is left under the floor and through the piers from end to end of the bridge. This affords space for a double track location for future tracks if they should be needed.



(Courtesy of the Engineering Record.)

FIG. 5.

FORM FOR PIER CONSTRUCTION IN PLACE; ARCHES COMPLETED.

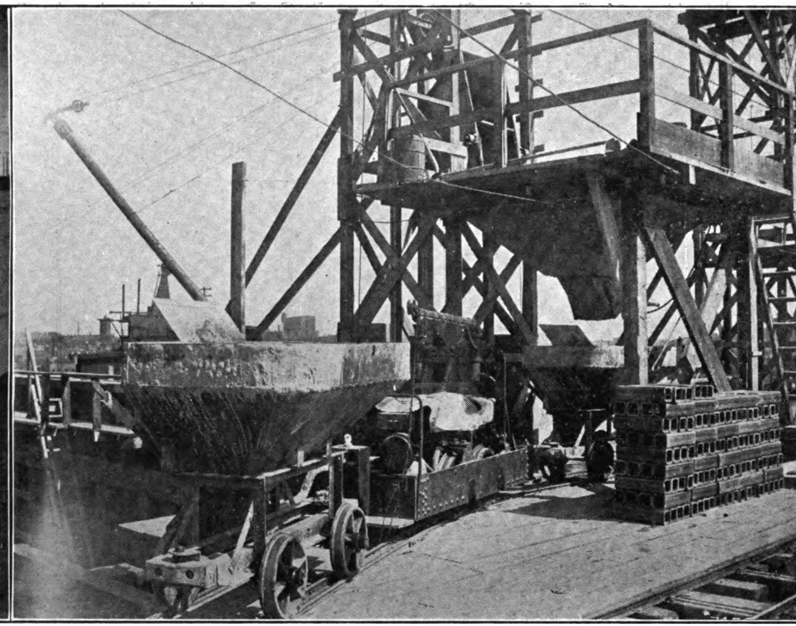


FIG. 6.

CONCRETE CAR, ELECTRIC LOCOMOTIVE, AND HOPPER ABOVE TABLE.

(Courtesy of the Engineering Record.)

Fig. 7.

CLOSE VIEW OF FALSEWORK, SHOWING RIB CENTERING AND CONSTRUCTION TRACK TRESTLE.

Probably the most notable feature of the work is the effort that has been made to have its lines architecturally pleasing. The design has been studied by a board of consulting architects of which Mr. Robert S. Peabody has been at the head. These gentlemen have given great attention to all details, even to the texture of the surface. To obtain the desired appearance the concrete is made exclusively of granite, of varying degrees of fineness, and cement, and the finishing is being done by skilled workmen. The care which has been devoted to the forms has resulted in eliminating the crude appearance often noticed in concrete construction.

Another interesting and somewhat unique feature is the method of executing the work. This has been done by the Boston Elevated Railway, directly, under the direction of Mr. George A. Kimball, Chief Engineer, and Mr. C. T. Fernald, Assistant Engineer, who have planned the complete plant for storage of materials, for mixing and delivering the concrete, and for the construction and removal of forms. Briefly speaking, the plant consists of a storage and mixing yard at the Cambridge end, connected with the Boston & Maine freight tracks, and provided with a hoisting elevator, by means of which the concrete is raised to a hopper well above the top of the bridge. From this, it is dumped into cars running on a narrow gauge track the whole length of the bridge and propelled by an electric locomotive. All power is electric, the current being furnished by the railway system.

The main structure has now been completed from the Cambridge end to the draw, and a fair idea can be gained of its appearance from a casual inspection, though the appearance of the completed structure will be greatly enhanced by the addition of the parapet railing. The location of the structure, adjoining the dam, affords an unusually favorable opportunity for observation.

THE ANTIQUITY OF IRON

ALBERT SAUVEUR

Archeologists concluded long ago, from the results of their researches into the history of the past, that the earliest tools, weapons and other implements of the inhabitants of this world were made of stone, and that as they became more civilized, stone was replaced by brass, which in turn was later displaced by iron, the use of iron indicating a still greater advance in civilization. The development of the human race was accordingly divided into three great periods; namely, the Stone, Brass and Iron Ages.

This theory which ascribes to the use of iron a relatively recent origin and considers it an indication of a relatively advanced stage of civilization, met at first with little opposition, and to a great extent is still the prevailing one.

More recent researches and studies of many eminent archeologists, hieroglyphists and philologists, however, have brought to light numerous evidences strongly opposed to the theory of the three ages, the correctness of which is now doubted by the most authoritative students of the prehistoric use of iron.

The belief in the existence of three distinct periods or ages corresponding to as many steps in the advance of civilization was based upon the fact that in ruins and other piles of rubbish of very great antiquity, no iron implements were found, while flint knives, hatchets and other instruments of stone were frequently discovered, and brass implements occasionally. The very important consideration that owing to their rapid destruction when subjected to oxidizing conditions, implements of iron could only be preserved for so many centuries under exceptionally favorable circumstances, was altogether overlooked by the advocates of the theory. Moreover, iron implements have been found, together with instruments of stone, in these remnants of past civilization, and it must be admitted that the authenticated find of a single object of iron in ruins belonging to the Stone Age must be fatal to the hypothesis.

The evidences of the early use of iron by the ancient races of Northern Africa and Western Asia, the Egyptians, Chaldeans, Babylonians and Assyrians, are many and conclusive. Iron and steel are frequently mentioned in the Old Testament. Tubal-Cain who was born in the seventh generation from Adam (some 3000 to 4000 years before Christ, according to biblical chron-

ology), is described in Genesis (revised version of 1885) as "The forger of every cutting instrument of brass and iron." The references to iron in Deuteronomy would indicate that in the time of Moses (some 1700 years B. C.), the Egyptians and Israelites were engaged in the manufacture of iron and familiar with its use. The book of Job contains many allusions to iron. In the history of the wandering of the children of Israel led out of Egypt by Moses, iron is frequently mentioned. It is also stated in the Bible that iron was used extensively by the Canaanites and during the reign of David and of Solomon. When David built the temple about 1000 B. C., he "prepared iron in abundance for the nails for the doors and for the joinings."

The frequent occurrence in hieroglyphic inscriptions of the Egyptian word Benipe (stone of the sky), and which in all probability stands for iron, would indicate that that metal was known by the Egyptians during the reign of the sixth or seventh king of the first Memphis dynasty (some 3000 B. C.). Other hieroglyphic inscriptions suggest the use of iron by the Egyptians as early as the third dynasty. From a careful study of painted hieroglyphics it seems highly probable that the implements painted blue were designed to represent iron and steel, and if this inference be correct the occurrence of these painted inscriptions would indicate that iron was used by the Egyptians during the fourth dynasty. Iron sickles and other tools of that metal are pictured on the tombs of Memphis (a city which was founded by Menes, the first king of the first dynasty), and at Thebes, another very ancient city. At a very early time blocks of granite and other hard stones were worked in Egypt, and, in the light of our present knowledge of the properties of metals, it is not possible to conceive that any other metal than iron could have been used to carve them. The oldest and most magnificent of these ancient Egyptian stone structures are the pyramids at Gizeh, and unless their builders possessed the art of conferring to their brass tools the hardness of steel, it must necessarily be inferred that the cutting of these blocks was accomplished by the use of steel, and as the pyramids were built during the third and fourth dynasties the use of iron in Egypt must be of equal antiquity. The Greek historian Herodotus refers to iron and steel having been employed in the construction of the pyramids. The erection of these stupendous structures by the Egyptians, however, was not considered by many conclusive proof of the use of iron at the epoch. It was argued that the builders must have possessed some other means of carving the stone, for had they used iron tools, some of

them would surely have been found in the vicinity of the pyramids. It was also contended that had the manufacture of iron been coeval with the building of the pyramids, some remnants of iron works would have been discovered in Egypt. In this reasoning the readiness with which iron oxidizes, already alluded to, causing its rapid decay when exposed to the air or to moisture, was ignored. In relatively recent years, moreover, some important discoveries have been made which seem to dispose of the arguments of those who would deny this early use of iron. In 1837 a piece of iron was discovered embedded in the solid masonry of one of the pyramids, which must be as old as the pyramid itself, for it is hardly conceivable that it could have been placed where found, at a later date. An iron sickle was found by Belzoni under the feet of one of the sphinxes at Karbak, which must have been placed there some 600 years B. C. Both these relics are preserved in the British Museum. In 1837 the ruins of extensive iron works and large slag heaps of great antiquity were discovered by Mr. Hartland, near the Well of Moses, in the Sinaitic Peninsula, an event of great importance to Egyptologists. A small piece of iron was found under the obelisk which was removed from Alexandria to New York in 1880. This obelisk was erected by Thothmes, the third, at Heliopolis some 1600 years before Christ, and removed to Alexandria some 22 years before the Christian era, when the piece of iron must have been placed under it. Many articles of iron found at Thebes are now preserved by the New York Historical Society. A picture of an actual Egyptian forge and bellow was discovered by Gardner Wilkinson in some monument at Thebes dating from about 1500 B. C.

The testimonies of the early use of iron by the Babylonians, Chaldeans and Assyrians, contemporaries of the Egyptians, are quite as conclusive. Many iron implements have been found in Mesopotamia dating from 1000 B. C. or from an even earlier period. Several tools of iron are preserved in the British Museum which were found by the antiquarian Laynard in ruins of great antiquity at Nineveh. Numerous inscriptions also testify to the early use of iron by these nations.

Whether iron was used in India, China and Japan before or after it was known to the Egyptians remains to a great extent a matter of speculation. It is certain, however, that these nations were familiar with this metal at the earliest period of their history with which we are cognizant. Iron and steel tools can be seen in the British Museum probably 3000 years old, which were

found in excavations in India. The Indian steel called Wootz was made in India long before the Christian Era and was used by the celebrated sword makers of Damascus. A famous wrought iron pillar or lath, which still stands at the principal gate of an ancient mosque near Delhi, in India, testifies to the ability of this ancient people to produce and work large masses of iron, and which according to sanscript inscriptions, were erected some 4000 years before Christ. Indeed how such a bulk of iron could have been forged by them still remains unexplained. The column stands 22 feet above the ground while its total length is 60 feet. It measures 164 inches in diameter at the base and 125 inches at the top and its weight probably exceeds 17 tons. Iron beams similar to those used in modern structures have been found in ruins of Indian temples of great antiquity.

So little is known of the early history of China and Japan that it is quite impossible to trace the origin of the use of iron in those countries. Mentions of iron, however, are found in the most ancient of Chinese writings, some of them dating back to 1000 B. C. It is alluded to in a Chinese record supposed to have been written some 2000 B. C. We have likewise evidences of the early use of iron in Japan, Persia, and Corea.

Passing from these ancient inhabitants of Africa and Asia to the more modern races of Europe we find that the Greeks who were the first European nation to attain a high degree of civilization, were acquainted with the manufacture and use of iron at the earliest period of their history of which we have any authenticated record. Their metallurgical knowledge, like so many of their other arts, was undoubtedly obtained from the Egyptians. Both iron and steel are frequently mentioned by early Greek writers and especially by Homer and Hesiod who lived in the ninth century before Christ, and by Herodotus who lived during the fifth century before our era. From the allusions of Homer it must be inferred that the Greeks were, at the time of his writing, acquainted with the art of tempering steel. Sophocles, who lived in the fifth century before Christ, also speaks of the tempering of iron in water.

The Romans acquired an early knowledge of iron through the Greeks and the Etruscans, who as well as the Greeks were familiar with that metal. Iron is frequently mentioned in the ancient records of the history of Rome, which city was founded 753 years before the Christian era. It is alluded to repeatedly in the writings of Pliny, the great Roman naturalist, who died in 79 A. D. It is quite certain that swords and javelins were made

by the Romans as early as 400 B. C., while iron agricultural implements are of still greater antiquity.

The Romans imparted a knowledge of iron to all the nations which they conquered. The Gauls, however, were acquainted with the metal before the Roman invasion, for iron weapons were used by them in their battles with the Romans hundreds of years before Christ. The famous Toledo blades were likewise manufactured in Spain long before the Roman conquest (192 B. C.).

To the thoughtful student of the early use of iron, it must appear from a careful consideration of the evidences collected by antiquarians, archeologists, hieroglyphists, and philologists that iron implements were used jointly with stone implements, by the nations of the world as far back as we can penetrate into their history, and that the previous existence of earlier stone and brass implements remain, therefore, a matter of mere speculation. The earlier use of brass implements to the exclusion of instruments of iron, is further opposed by metallurgical considerations, for the production of brass implies a greater knowledge of metallurgy and suggests more complicated and skilful operations than the production of small masses of iron from rich iron ore. Indeed the reduction to the metallic state of nearly pure oxide of iron such as is abundantly found in nature, by means of charcoal or other carbonaceous fuel, is one of the simplest metallurgical operations and it is highly probable that the primeval man became acquainted with this process long before acquiring the greater knowledge and greater skill necessary for the manufacture of brass.

To sum up, and as might have been anticipated, the earliest evidences of the use of iron by man, are found in the ruins and inscriptions of Egyptian, Babylonian, Chaldean and Assyrian monuments, that is in relics left to us by the oldest nations of which we have some authenticated historical knowledge, and the first to attain a high degree of civilization. Owing to the obscurity which pervades the early history of China, Japan, India and other surrounding countries, it is not possible to know whether the use of iron by these nations preceded or not the use of the metal by the Egyptians. The Greeks obtained their knowledge of iron from the Egyptians and in turn imparted it to the Romans by whom finally it was disseminated through the other European nations, some of whom developed into the powerful metallurgical nations of the present day, while in Africa and Asia the manufacture of iron has practically ceased, and is carried to a very inconsiderable extent by the modern Greeks and Romans.

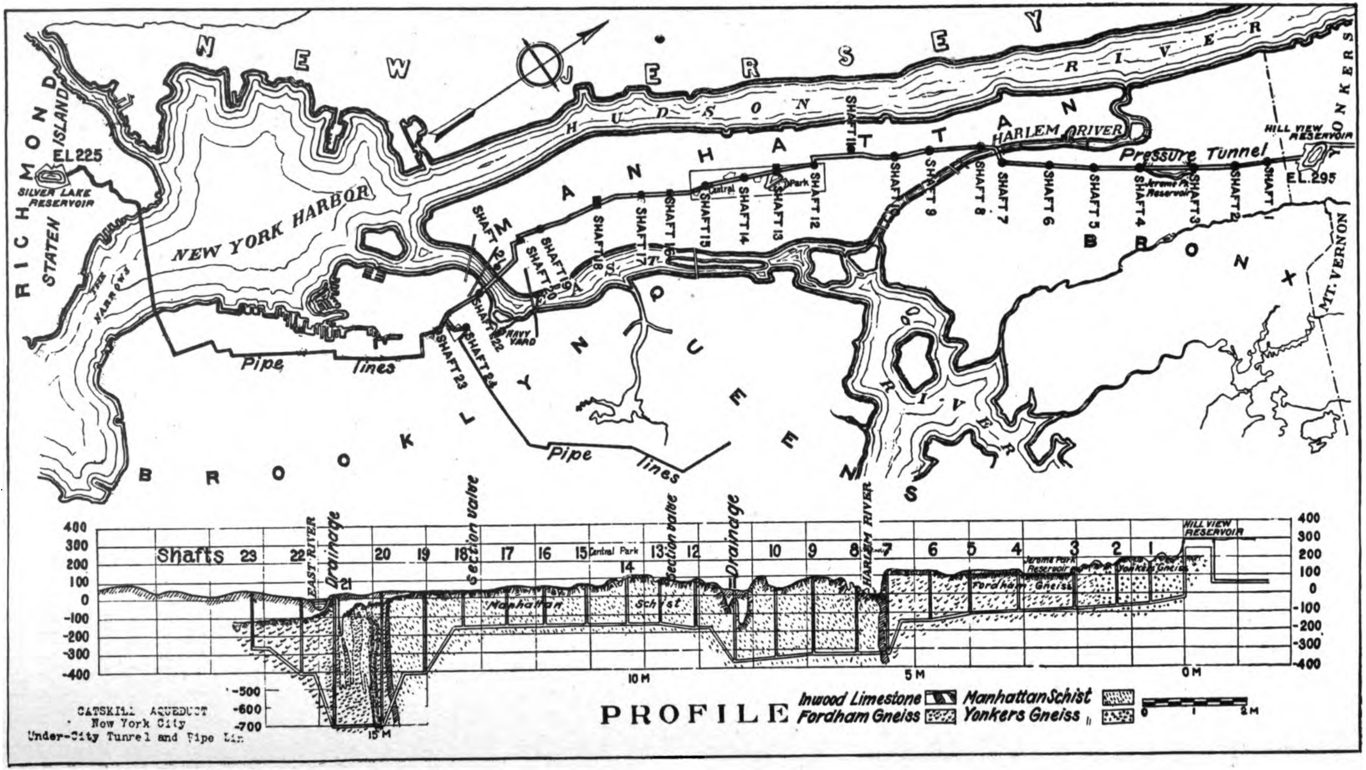

NEW JERSEY
HUDSON RIVER
YONKERS
MT. VERNON
HILL VIEW RESERVOIR
EL.295
Pressure Tunnel
HARLEM RIVER
MANHATTAN
BRONX
QUEENS
BROOKLYN
RICHMOND
STATEN ISLAND
EL.225
SILVER LAKE RESERVOIR
NEW YORK HARBOR
THE NARROWS
Pipe lines
Central Park
Jerome Pk. Reservoir
NAVY YARD
SHAFT 1
SHAFT 2
SHAFT 3
SHAFT 4
SHAFT 5
SHAFT 6
SHAFT 7
SHAFT 8
SHAFT 9
SHAFT 10
SHAFT 11
SHAFT 12
SHAFT 13
SHAFT 14
SHAFT 15
SHAFT 16
SHAFT 17
SHAFT 18
SHAFT 19
SHAFT 20
SHAFT 21
SHAFT 22
SHAFT 23
SHAFT 24
Shafts
EAST RIVER
Drainage
Section valve
HARLEM RIVER
Manhattan Schist
Fordham Gneiss
Yonkers Gneiss
0 M
5 M
10 M
15 M
PROFILE
Inwood Limestone
Manhattan Schist
Fordham Gneiss
Yonkers Gneiss
CATSKILL AQUEDUCT
New York City
Under-City Tunnel and Pipe Lin

Fig. 1.

UNDER-CITY TUNNEL FOR DELIVERING CATSKILL WATER TO THE DISTRIBUTION MAINS OF NEW YORK*

ALFRED DOUGLAS FLINN

Department Engineer, Board of Water Supply

When, in 1905, the great scheme for obtaining from the Catskill mountains an additional supply of 500,000,000 gallons daily of pure and wholesome water for New York was planned, the details of the conduits for delivering this water to the five boroughs of the City were not fully worked out. The several water supply systems of Greater New York, principal among which are the Croton, used by Manhattan and The Bronx since 1842, and the Ridgewood, used by Brooklyn since 1858, are not inter-connected. Staten Island — the Borough of Richmond — self-sustaining until now, by geographical necessity is using local well water of inferior quality. The Borough of Queens is served by several private water companies. Both the Long Island boroughs draw principally from vast underlying sand strata, now taxed to their safe limit, so far as developed, while the Island of Manhattan as well as the Borough of The Bronx, forming part of the mainland, are supplied almost entirely from the Croton watershed by two aqueducts completed, respectively, about 1842 and 1891. The old Croton aqueduct crosses the Harlem river on the celebrated High Bridge, while the new aqueduct dives under in a pressure tunnel through solid rock. In Manhattan, the latter aqueduct, of 300,000,000 gallons daily capacity, terminates in a large gate chamber, whence eight main pipes, 48 inches in diameter, extend downtown under the avenues and streets.

To distribute the entire Catskill supply through pipe mains in such a way as to economize the available gravity pressure would require the equivalent of sixteen 66-inch steel or thirty 48-inch cast-iron pipes, at an estimated cost of $47,000,000. But the laying of so many miles of great pipes would necessitate digging up many busy streets, with all the attendant annoyances and dangers, and the unavoidable indirect losses to business along the routes.

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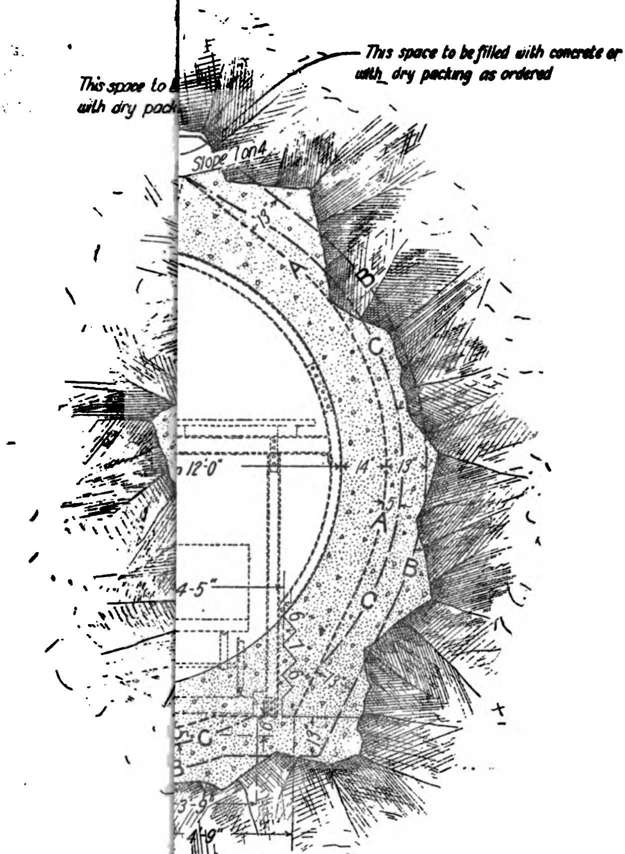
* Other features of the Catskill water works described in the JOURNAL are "Some Geological Features Affecting the Catskill Water Supply," by James F. Sanborn, June, 1908, and "Dams for Catskill Water Works," by Alfred D. Flinn, November, 1909.

Furthermore, the streets are already so occupied by pipes, sewers and conduits, and by subway, surface and elevated railways, or have been so pre-empted for future subways and other sub-surface structures, that to obtain locations for even a few large new water mains was scarcely practicable. Fortunately, the geology of the city offered a much safer, more convenient, far more permanent and more economical solution of this difficult waterworks problem through the most congested portions of the metropolis. In other words, the underlying rocks, for the most part sound and strong, made feasible one great conduit, — a pressure tunnel deep in the rock — from Hill View reservoir, just north of the city line in Yonkers, to the heart of Brooklyn, traversing the Boroughs of The Bronx and Manhattan, and passing under the Harlem and East rivers. Extensive explorations with core drills demonstrated that such a tunnel was practicable, and other studies indicated that it, with large pipe lines extending from its Brooklyn termini into Queens and Richmond boroughs, could be constructed for but little more than half the cost of the all-pipe delivery system.

In the exhaustive studies more recently made for planning the interborough delivery, the speed and general success with which 17½ miles of pressure tunnels are now being built north of the city for the Catskill aqueduct emphasized the desirability of this type of conduit.

The governing factor in the tunnel's general location, as well as in its adoption, was the existence of tunneling rock at reasonable depth. The rock formations of New York City are mostly well known types in which tunneling has been extensive and successful. To be sure, there are difficulties to be overcome, as in all tunneling. In The Bronx and Brooklyn the prevailing types of rock are gneiss, and on Manhattan island schist. At the Harlem river and the old location of the East river, in the Bowery district of the lower East Side, Manhattan, dolomitic limestone is found in relatively narrow beds, and, at the latter place, interbedded with gneiss formations. The distance to which the tunnel was projected in Brooklyn was determined mainly by two considerations: first, beyond the locality chosen for the termini, the quantity of water to be carried in any one conduit was too small to make tunnel construction economical; second, the surface of the ledge rock had descended to such depth that it was not feasible to sink shafts to it through the overlying drift materials since with the exception of the upper 20 to 50 feet, approximately, the shafts are below tide level. Hence compressed air or similar highly ex-

CONTRACT 66 SHEET 17
SHEETS IN SET, 32



14" TO "A" LINE"

City of New York
BOARD OF WATER SUPPLY
ATSKILL AQUEDUCT
D TYPES OF PRESSURE TUNNEL
A AND B, 12'-0" DIAMETER

1 0 1 2 3 4 5 Ft
100 0 40 80 120 160 Cm

OCTOBER 15, 1910

Drawn J.R.P.
Traced G.H.B.
Checked T.C.
Thos. H. Wiggins
Designing Eng

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ROBERT A WELCKE PHOTO-LITH., 178 WILLIAM ST N Y

Ref-Acc 10406-11206

pensive construction becomes necessary, and the depth to which pneumatic work can be carried is limited by human endurance.

For constructing the tunnel 24 shafts will be sunk, ranging in depth from 200 to 750 feet. The most northerly, Shaft 1, will be sealed after the tunnel is completed and not further used. Shafts 11 and 21, in the depressions in the profile just mentioned, will be equipped as drainage shafts, by means of which the tunnel, or parts of it, can be unwatered for inspection or repairs, if, in the distant future, the latter should become necessary. At Shafts 13 and 18, (see map and profile) all-bronze, hydraulically-operated gate valves will be placed across the tunnel, thus dividing it into three sections; these two valves have consequently been named: section valves.

Into all shafts, except Numbers 1 and 11, one or two steel pipes, designated as risers, are to be built, imbedded in and lined with concrete, thus affording connection from the tunnel to the distribution mains in the streets. Each riser will be covered at its top with a bronze casting, termed a shaft cap, and shaped much like a pipe cross, the bottom being fastened to the top of the steel riser and the top covered by a domed cover bolted on. The two horizontal outlets, usually 30 inches in diameter, each will have an all-bronze, screw-operated gate valve bolted to its flange, beyond which other valves, Venturi meters, pressure regulators, etc., will make up the connections to the distribution pipes.

The valves and meter registers at each shaft will be contained in a large concrete chamber. At Shaft 3, for connection to Jerome Park reservoir, and in Shafts 23 and 24, the Brooklyn termini, the risers will be 72 inches in diameter inside their concrete linings; all the other risers will be 48 inches in diameter. By removing the domed cover from each shaft cap access can be had directly into the tunnel whenever the later is unwatered.

As a safeguard against the serious result of an accident to the works at the head of a shaft, and for convenience in certain operations, a special valve is to be placed at the bottom of each riser. These have been named riser valves and will be wholly of bronze and so designed as to work either automatically, or by manipulation in the valve chamber, or at a distance by means of electricity. The several valves and fittings just mentioned and the usual arrangement of a shaft are indicated by accompanying drawings.

The shafts are spaced from 2300 to 5200 feet apart. Fortunately, it has been possible to locate the tunnel so as to bring most of the shaft sites in public parks or large open spaces at the

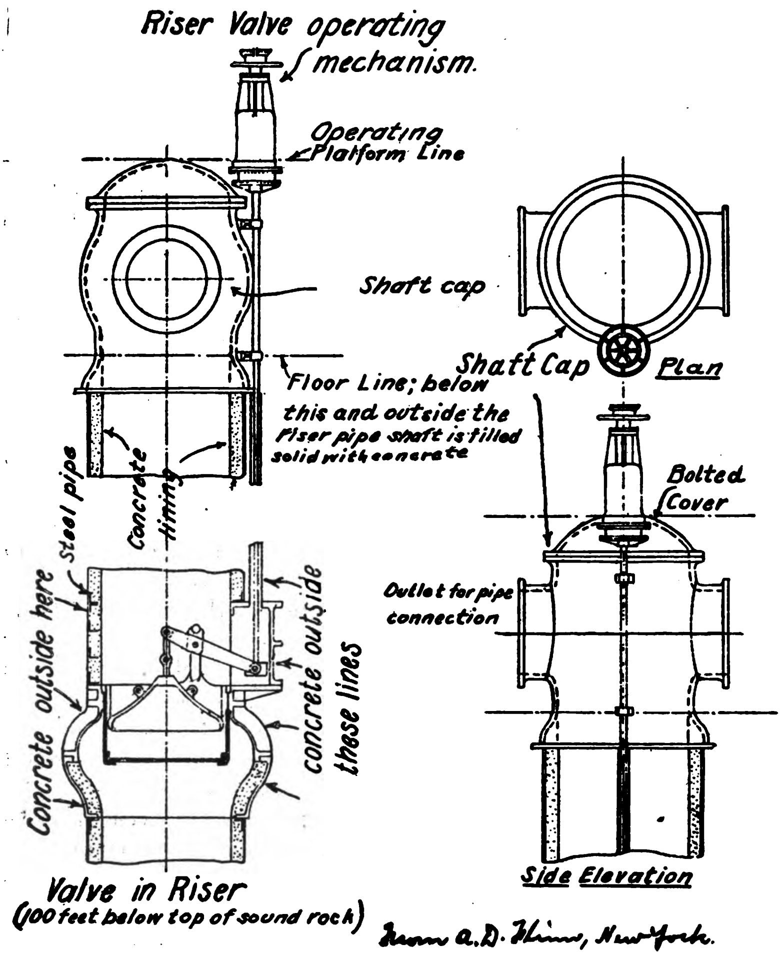
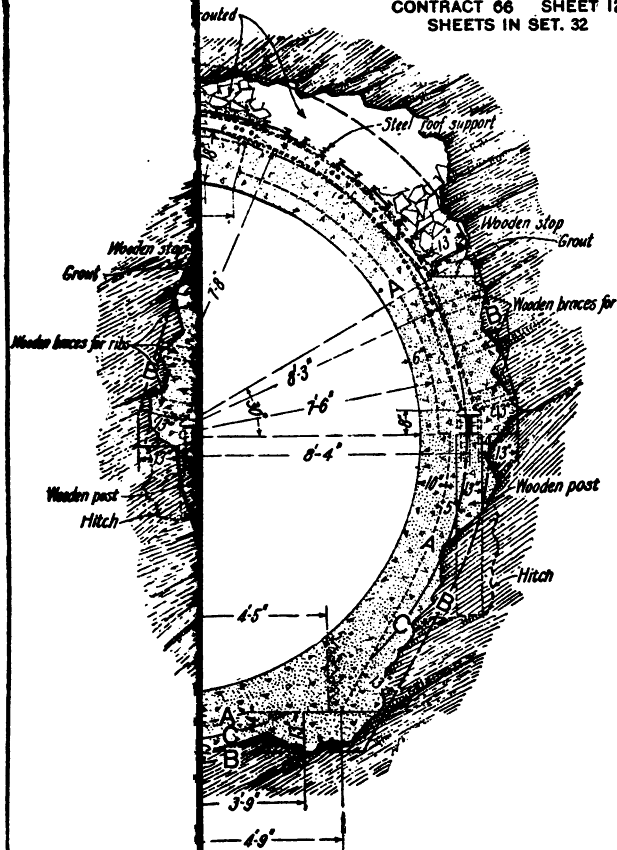

Riser Valve operating mechanism.
Operating Platform Line
Shaft cap
Floor Line; below this and outside the riser pipe shaft is filled solid with concrete
Steel pipe
Concrete lining
Shaft Cap
Plan
Bolted Cover
Outlet for pipe connection
Concrete outside here
concrete outside these lines
Side Elevation
Valve in Riser
(100 feet below top of sound rock)

Fig. 4.

CONTRACT 66 SHEET 12
SHEETS IN SET. 32



10" TO "A LINE"

D₃

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Excavatio
Concrete
Dry pack
Grout
Steel ribs
Timber in p
Steel laggi
Temporary

Drawn G.E.M. J.D.
Traced E.F.F.
Checked J.D. L.C.W.
Thos. H. Wiggin
Designing Eng

Ref - Acc 10811, 12529, 11119, F.J.3

City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
PRESSURE TUNNEL
TYPES C_3 AND D_3, 14'-0" DIAMETER

1 0 1 2 3 4 5 Ft
100 0 40 80 120 160 Cm

DECEMBER 1. 1910

File Cont - 5432 C Acc 12466

ROBERT A. WELCKE PHOTO-LITH. 78 WILLIAM ST. N. Y.

intersections of avenues and streets. In only three cases are shafts located on private property which will have to be bought, although, in one or two other cases, private property will be secured for temporary use during construction. With the exception of a few hundred feet, the tunnel is located beneath public property. Such location results in great economy, avoiding purchase of easements in expensive real estate, and also avoiding the possibility of having plunger elevator shafts, artesian (!) wells, or similar borings sunk into the tunnel, with the consequent trouble.

This tunnel is about 18 miles long; its location and profile are shown on the accompanying map. For 41,750 feet, beginning at Hill View reservoir, its internal diameter will be 15 feet; beyond which the lengths and diameters are as follows: for 24,530 feet, 14-foot diameter; for 4,500 feet, 13-foot diameter; for 9,130 feet, 12-foot diameter; for the remaining 15,000 feet, including the 1800-foot branch tunnel in Brooklyn, 11-foot diameter. Throughout its length the tunnel will be lined with dense, strong Portland cement concrete, and the rock will be thoroughly grouted under pressure back of this lining. The object of this treatment is to render the tunnel as watertight as feasible. Smooth lining, of course, also greatly enhances the hydraulic capacity of the tunnel and makes its cleansing easier. The diameters of the hole in the rock will be roughly 4 feet greater than those of the finished tunnel bore.

To withstand, with an abundant margin of safety, the unbalanced bursting pressure due to the elevation of Hill View reservoir above the ground water table over the tunnel it was decided that the minimum depth of sound rock above the tunnel should be 150 feet. As a matter of fact the depth of the tunnel in sound rock is everywhere greater than this minimum, and, for a large part of its length much greater, as shown by the profile. The depths below the surface of the ground range from 200 to 750 feet. Two deep depressions in the profile were necessary. The northerly drop passes beneath the Harlem river and Manhattanville valleys, and the southerly, beneath the old bed of the East river. At both places geologic faulting and the action of water have weakened the rocks to great depth.

The riser valves are so designed that each can be readily disengaged from its settings, without staging, and lowered to the tunnel or raised to the chamber as a unit. Thus any shaft can be quickly cleared for access to the tunnel, after unwatering. The hydraulic cylinders for operating the section valves will be in the chambers at the tops of their shafts.

Each drainage shaft is located about 75 feet from the tunnel and is connected with it by a horizontal drift which contains a hinged, dome-shaped, elliptical bronze door, or valve. It is thus possible to shut the shaft off completely from the tunnel and to empty it while the tunnel is in service. A steel float, shaped like a huge milk can, will be placed in each drainage chamber. Electrically driven centrifugal pumps, with their motors, will be installed in the float whenever the tunnel is to be unwatered and will descend with the water level during pumping until the float rests on the bottom of the shaft. After the work in hand is completed, the bronze door and other valves can be closed and the tunnel refilled. By refilling the drainage shaft through a pipe provided for the purpose the float is returned to the surface, permitting the machinery to be dismantled and suitably stored.

From each chamber a drain will extend to a nearby sewer or water course, thus keeping the floor free from water. Each chamber will have electric lights and a ventilating fan which can be set in operation as soon as the attendant enters the chamber. The tendency of various noxious gases to accumulate in such deep chambers and manholes renders ventilation imperative. Access to each chamber will be by means of a trap door opening on to a stairway. Frequent visits to these chambers will be necessary.

By reversing the normal direction of flow in the pipe lines and tunnel it will be possible to draw upon the Brooklyn system and the 400,000,000-gallon terminal reservoir in Richmond and thus to send water to The Bronx and Manhattan. The new City aqueduct thus incidentally inter-connects all the important water supply systems of Greater New York.

The many advantages of the deep under-city tunnel over subsurface mains of equal capacity are perhaps specially prominent in New York, where urban pressure tunnel construction originated in the Harlem river crossing and adjacent portions of the new Croton aqueduct, placed in use in 1891 and uninterruptedly in service since that time. Through this new City tunnel it will be possible to deliver Catskill water by gravity to the twentieth stories of tall buildings in the downtown districts, after the necessary changes have been made in the distribution pipes. This high-pressure gravity supply, it has been estimated, will permit the elimination of public and private pumping now costing about $2,000,000. per annum. It will afford better fire protection. It is anticipated that construction will begin next spring and that about 4½ years will be required for the work.

Messrs. John A. Bensel, Charles N. Chadwick and Charles A. Shaw are the Commissioners of the Board of Water Supply, and Mr. J. Waldo Smith is Chief Engineer, and Mr. Merritt H. Smith is Deputy Chief Engineer. Mr. Walter E. Spear, Department Engineer, is to have charge of the City Aqueduct construction, and for some time has had immediate charge of the surveys. The preliminary studies and surveys and the preparation of the designs and specifications have been carried on under the writer's direction, with Mr. Thomas H. Wiggin as senior designing engineer and Mr. Percy C. Barney as principal assistant engineer.

THE THERMOS BOTTLE

FRANCIS PARKMAN COFFIN, '03

The thermos bottle is now so frequently used for keeping liquids warm, such as coffee and other foods, that it has become a familiar and useful article. In its original form, the Dewar flask, it was used for storing liquid air. For this purpose a flask is required with thermally insulated walls which will allow the minimum ingress of heat to the liquid air whose temperature is about — 188° Centigrade, or 208° below the average room temperature of 20°C. Every heat unit which leaks in, causes the loss by evaporation of a small portion of the liquid air.

The Dewar flask (Fig. 1) consists of a double walled spherical glass bulb with a long cylindrical neck, the inner and outer walls being sealed together at the top of the neck, leaving a space elsewhere of ¼ to ⅜ of an inch between the walls. During manufacture a tubular vent is left in the bottom of the outer bulb, through which is introduced a silvering solution, consisting of silver nitrate, with which is mixed a solution of other salts just before applying it to the bulb. The addition of the second solution precipitates the silver from the nitrate in the form of a uniform metallic coating on the glass, both on the outer side of the inner bulb and on the inner side of the outer bulb. This silver coating forms a mirror with excellent reflecting power for heat and light rays. In fact it is in this manner that mirrors are made for the reflecting type of telescope for astronomical work.

The coefficient of reflection of a clean silvered surface for the ultra-red or thermal rays varies from about 97% to 99% according to the wave length. As the coefficients for absorption and radiation are equal, and are the complement of the coefficient of reflection, it will be seen that they represent only 1% to 3% of the incident radiation on a silvered surface. A glass surface, on the other hand, has a coefficient of reflection of about 10% and a coefficient of absorption and radiation of about 90% for thermal rays; glass being opaque to all the longer ultra-red rays such as are emitted by bodies at temperature of 100° or 200°C.

In order to take advantage of the above characteristics of a silvered surface, the air must be exhausted from the space be-

tween the silvered walls to reduce convection of heat from one to the other to a minimum. For this purpose the flask is placed in a gas oven and raised to a temperature of about 350°C, while the vent tube is connected to a vacuum pump, such as is used in exhausting incandescent lamps. The high temperature in the oven drives off all air or moisture which would otherwise adhere to the walls. Then the vent tube is sealed off from the pump by fusing the walls together, leaving a high vacuum in the jacket. The best pumps used are capable of exhausting to a residual pressure of about 1 micron of mercury, or nearly one millionth of an atmosphere. The vacuum, incidentally, protects the silver

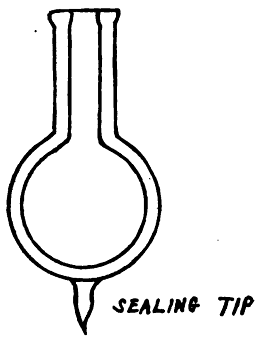

Fig. 1

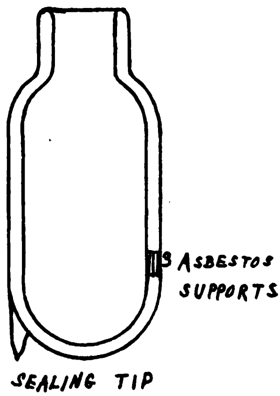

Fig. 2

coating from tarnishing and maintains the coefficient of reflection at a value fairly near to that mentioned for clean silvered surfaces.

Heat leakage is practically reduced to radiation between the walls of the jacket, a small amount of conduction through the walls of the neck and a little convection by vapor in the neck.

In either the liquid air flask or the thermos bottle (Fig. 2), the inner bulb assumes the temperature of the liquid within while the outer bulb assumes the temperature of the atmosphere.

It is apparent that the silvered surface of the warm inner bulb (in the thermos bottle) will radiate a small amount of heat and that the outer wall will absorb only a small portion of this, reflecting most of the rays back on the inner bulb. Here a small percentage is absorbed while the rest is reflected to the outer

wall again. Thus the rays emitted from the inner bulb will be reflected back and forth until half their energy has been absorbed by each wall and the net radiation across the jacket will be one-half the initial radiation from the inner bulb. The initial radiation is proportional to the difference of the fourth powers of the absolute temperatures of the two walls. In the liquid air flask the same phenomena occur, but with the temperature gradient reversed.

A series of cooling tests were made to determine the relative rates of heat emission from glass flasks of various construction. With the exception of one cylindrical thermos bottle (Fig. 2), these flasks were all spherical (Fig. 1) and represented five varieties:

1. Single walled clear glass flask.
2. Double walled clear glass with air jacket.
3. Double walled clear glass with vacuum jacket.
4. Double walled silvered glass with air jacket.
5. Double walled silvered glass with vacuum jacket.

These flasks were filled with water heated as near to boiling as possible and thermometers inserted in each neck through a hole in a cork stopper. All empty space in the neck was filled with cotton to prevent convection of heat by circulating vapor. They were then hung by their necks in a sheltered corner of a room and thermometer readings taken at regular intervals.

From the rate of cooling was calculated the radiation in watts per square inch of surface for the inner bulb without making any corrections for escape of heat through the neck.

Record of Tests

Class 1. Single Walled Clear Glass Flask

Bottle No. F—1—3½″ diameter

Time Minutes	Temp. C Water	Room	Drop	Radiation Watts Per Sq. In.
0	91°	20°	—	——
15	78		13°	0.74
30	67		11	0.62
45	60		7	0.40
60	54		6	0.34
75	48	21	6	0.34

Bottle No. F—2—7″ diameter

Time Minutes	Temp. C Water	Room	Drop	Radiation Watts Per Sq. In.
0	88°	20°	—	——
15	82		6°	0.52
30	77		5	0.43
45	73		4	0.34
60	69		4	0.34
75	65	21°	4	0.34
90	62		3	0.26

Class 2. Clear Glass with Air Jacket

Bottle No. C — 2 — 2¾″ x 3¾″ diameter

0	94°	20°	——	——	
15	85		9	0.32	
30	78.5		6.5	0.23	Average 0.285
45	70		8.5	0.30	
60	62	19°	8	0.28	
75	58.5		3.5	0.13	

Bottle No. C — 3 — 2⅝″ x 3⅝″ diameter

0	93°	20°	——	——
15	82	20	11	0.35
30	72.5	20	9.5	0.30
45	66	20	6.5	0.205
60	59.5	18	6.5	0.205

Class 3. Clear Glass with Vacuum Jacket

Bottle No. C — 1 — 3″ x 3½″ diameter

Time Minutes	Temp. C Water	Room	Drop	Radiation Watts Per Sq. In.	Difference of 4th Powers
0	95°	20°	——	——	——
15	89		6	0.24	0.24
30	83		6	0.24	.24
45	77.5		5.5	0.22	.202
75	69		8.5	0.17	.177
120	58	19	11	0.15	.135

Bottle No. C — 3 — 2⅝ x 3⅝″ diameter

0	92°	15°	——	——	——
15	83		9	0.285	0.285
30	75		8	0.25	.26
45	70		5	0.175	.215
60	64		6		
75	58.5		5.5	0.175	.17

Class 4. Silvered Glass with Air-jacket

Bottle No. S — 2 — Cylindrical, 2½″ x 2¾″ diameter x 6″ long

Time Minutes	Temp. C Water	Room	Drop	Radiation Watts Per Sq. In.
0	93.5°	19°	——	——
15	87		6.5	0.26
35	80		7	0.21
45	77		3	0.18
60	72	20	5	0.20

Bottle No. S — 4 — 2⅝″ x 3⅝″ diameter (same bottle as No. C—3)

0	94°	19°	—	——
15	84		10	0 32
30	77		7	0.22
45	72		5	0.16
60	67		5	0.16
75	62	20	5	0.16

Class 5. Silver Glass with Vacuum Jackets

Time Minutes	Temp. C Water	Temp. C Room	Drop	Radiation Watts per Sq. In.
Bottle No. S — 1 — 3½″ x 4″ diameter				
0	95°	20°	—	——
30	94		1	0.028
60	94	21	0	——
200	90		4	0.025
315	88		8	0.015
			Average	0.019
21 hours	71	19		0.015
Bottle No. S — 2 — Cylindrical, 2½″ x 2¾″ diameter x 6″ long				
0	92°	21°	—	——
25	90.5		1.5	0.036
85	86		4.5	0.045
150	82	23	4	0.037
215	79		3	0.027
290	75		4	0 032
345	72	22	3	0.033
			Average	0.035
20¼ hours	45	20		0.018
Bottle No. S — 3 — 4″ x 4½″ diameter				
0	92°		—	——
125	90	20°	2°	0.012
305	75	19	15	0.012
Bottle No. S — 3				
0	93.5°	19	—	
180	90	18	3.5	0.015 average
360	86	19	4	

Class 1, the single walled glass flasks, cooled more rapidly than any of the double walled bottles. Classes 2, 3 and 4 cooled at about the same rate, beginning at from .035 to 0.24 watts per square inch. This was about one-half the rate of Class 1. Exhaustion and silvering when applied separately did not seem to be of any decided advantage. In Class 5, where silvering and vacuum were used together, very different results are noticeable, the cooling being from ten to twenty times as slow. Class 5 is from 20 to 50 times better than Class 1. In Class 5 it will be seen that bottle No. S-2, the cylindrical thermos bottle lost heat a little more rapidly than the liquid air flasks, No. S-1 and No. S-3. This may have been due to the short wide neck and, possibly, to poorer silvering or exhaustion.

For comparison with the above results, I have appended some data on loss of heat through various materials used for steam pipe coverings, and in other places where thermal insulation is desired. These figures are taken from tables in Kent's Mechanical Engineers' Pocket Book and reduced to watts lost

per square inch for comparison with my data, which had been calculated in the units generally used in connection with the dissipation of heat from electrical machinery.

As the temperature differences between steam and air in these tests were considerably greater than in the case of the thermos bottle tests, I have reduced the figures in Kent's tables in direct proportion to the temperature differences. This places all figures on the basis of approximately 71° (Centigrade) difference in temperature between source of heat and atmosphere, this being the average difference during the interval between the first two readings for the thermos bottles.

Steam Pipe Coverings

Substance (1 Inch Thick)	Heat Loss* (Watts per Sq. In.)	Air Included (Parts in 1000)
Sand	0.678	471
Fine Asbestos	0.534	919
Air alone	0.533	1000
Dry plaster of Paris	0.336	632
Ground chalk (Paris white)	0.224	747
Blotting paper wound tight	0.230	—
Asbestos paper wound tight	0.237	—
Paper	0.152	—
White pine charcoal	0.152	881
Loose lampblack	0.107	944
Light carbonate of magnesia	0.150	940
Compressed carbonate of magnesia	0.168	850
Best slag wool	0.142	—
Hair felt	0.112	815
Loose wool	0.088	944

Commercial Steam Pipe Coverings

Kind of Covering	Thickness (Inches)	Heat Loss† (Watts per Square Inch)
Bare pipe, 8-inch diam.		0.705
Hair felt	0.82	0.110
Magnesia	1.25	0.100
Manville sectional	1.70	0.092
Mineral wool	1.30	0.074

* Reduced from basis of 133° C. temperature difference to 71° difference by direct proportion.

† Reduced from basis of 151° C. temperature difference to 71° difference by direct proportion.

To make the comparison with the thermos bottles fairer, a further correction should be made for relative thickness of insulation, but this has not been done for the reason that the thickness of an inch of insulation, as given in Kent's tables, is as thin a packing as would generally be used in practice.

A reduction of this kind, however, would improve the relative showing of the thermos bottle. Bearing this in mind, it will be evident from these tables that the insulation afforded by the best solid packing materials is about the same as that afforded by the glass jackets in Classes 2, 3 and 4 of the thermos bottle tests. The real thermos bottle in Class 5, however, excels any of the solid packings, especially if they be applied in thicknesses of about ⅜ inch, which is the thickness of the thermos jacket.

The more efficient solid packings owe their effectiveness to porosity and to their ability to hold the air in these pores from circulating; they keep the air still by virtue of the roughness of the fibers or particles. Fine asbestos does not appear to be a very good insulator, in spite of its high content of imprisoned air, since its fibers are smooth and do not prevent the air from circulating.

THE APPOINTMENT OF EUGENE DUQUESNE AS PROFESSOR OF ARCHITECTURAL DESIGN

H. L. WARREN, h. '02

Another important forward step has been taken in the development of the Department of Architecture by the appointment of so distinguished an architect and teacher as Professor Eugene Duquesne to the chair of Architectural Design.

Every student of architecture is familiar with the world-wide reputation of the French Grand Prix de Rome, which makes the holder "pensioner of the Academy of France in Rome" with the advantage of residence at the well-known villa Medici, on the Pincian Hill, and four years of foreign travel and study. Mr. Duquesne's brilliant career as a student culminated in the winning of this prize in 1897, when he was twenty-nine years old.

Hitherto it has been taken for granted both in this country and in France that a former holder of the Grand Prix de Rome will make his career in his own country, since the winning of this coveted distinction opens all doors to success and especially assures ultimate appointment to such government positions as Professor Duquesne already holds. In order to come to us he gives up these important positions and he gives up his successful atelier (or studio for students of architecture) in Paris — or to put it more accurately, he transfers it to Harvard University; and although he finds it hard to leave behind him the many pupils and past pupils, who look to him for advice and guidance, he will find also in this country many former pupils — among them practicing architects of distinction — who will be glad to welcome him here. Many graduates of our Department of Architecture have been among his pupils so that the traditions of his atelier and of our school have already intermingled. But he will have to sever also his connection with the great Paris School of Fine Arts — his *alma mater* — where, since 1906, he has been a member of the Jury for Architecture, an appointment which gave official recognition to his work as a teacher. Mr. Duquesne further holds the official position of Architect of the French Government in charge of the domain of the palace of Versailles and the Trianon, in which position he has had to carry out important works of restoration and repair, both in the

palace itself and in the gardens. In his private practice he has also carried out important commissions and will be obliged to leave unfinished work of great interest, the conduct of which he will have to depute to others. He has, for instance, now under way the important Municipal Theatre for the city of Nancy, the ancient capital of Lorraine. This is of peculiar interest because it involves the preservation of the front of the old bishop's palace of the eighteenth century as the front of the new theatre, which is being built behind it. It may be of interest to note that the recent floods which affected the river Meurthe on which Nancy stands, as well as so many other rivers of France, threatened the destruction of the old palace front by washing out the foundations, and Mr. Duquesne was recently engaged with somewhat difficult works for the protection of this interesting piece of architecture, with which his design for the theatre has been made to harmonize.

The outline of Mr. Duquesne's career as a student, and as an architect, and the many distinctions and successes which he has won have already been given with so much fulness in the daily press that it seems hardly necessary to repeat the story. Enough has been said here to indicate the high regard in which he is held in his own country and to emphasize the good fortune of Harvard University in securing his services for the Department of Architecture. It will be seen at once that it can have been no easy task to induce him to give up an assured career at home for even so attractive a position as that offered him by the University. The enthusiasm of many of our foremost architects when they learned that an effort was being made to secure Duquesne, and their interest in our department of architecture, which led them strongly to second the proposal of the University as soon as they heard of it, counted for much with Mr. Duquesne, for their expressions to him made him feel that in coming to this country he would have the cordial support of the leaders of the profession here. But we owe even more to the direct advocacy of the Hon. Robert Bacon, '80, the United States ambassador to France, not only with Duquesne himself, but with the French government, in securing its support for his acceptance of the offer. Professor Duquesne comes to us to accept a permanent position; but he does so, not only with the official approval, but with the cordial support, of his government. This could of course not have been accomplished, but for the interest of many French friends of Harvard University and of others who are

interested in the movement to increase the intellectual influence of France in the United States. It may be regarded then as in a sense a part of that admirable international movement for intellectual exchange which has led in other directions to the exchange Professorships both with Germany and with France.

Some few words it may be desirable to add as to the personal quality of Mr. Duquesne. He is quiet and unassuming in manner, while at the same time he arouses in his students enthusiasm for their work, so that those who have been his pupils speak of him with regard and admiration both as a man and as a teacher. He is not only a designer of the very front rank, but is also an admirable draughtsman, and his work is known for its reserve as well as for its strength. The problem on which he won the Grand Prix de Rome in 1897 was a design for a Votive Church in a lofty situation. It was a departure from the accepted type of grand-prix project in that, while admirably balanced, it was frankly unsymmetrical, and the design was founded on that of the Cathedral of Florence, especially in the treatment of the great dome. It was doubtless this preoccupation with the Cathedral of Florence that led him to undertake as part of his work as holder of the Grand Prix de Rome a thorough analysis and study of the construction of this dome illustrated by careful drawings.

Mr. Duquesne has a very decided and practical belief in the intimate relation of structure and design. He is not of those on the one hand who believe that a building or other edifice can be designed with regard to its utility and its construction merely and then made into "architecture" by the addition of extraneous decoration or forms having little or nothing to do with the structure; nor on the other hand does he tolerate the idea that a good design for a building can be made with little or no regard for structural conditions — then to be held up by the good offices of the engineer. The principles for which the Department of Architecture has always stood: that structure and design in architecture are necessarily one, that the structure must be expressed in the design; consistency; restraint of design — these are the things for which Mr. Duquesne stands. In a recent letter he said, "the art of architecture is above all the art of constructing well, and consequently, that of composing always with construction in view." Undoubtedly he would sympathize with the significant statement of his countryman, the great architect Labrouste when he says that "architecture derives the elements

with which it produces its effects from the requirements of the building, and from the means of construction." Mr. Duquesne indeed is distinguished for his keen interest in construction and this interest has done much to give quality and character to his work as a designer. He has occupied himself a good deal with practical problems.

While holder of the Grand Prix de Rome he showed his breadth of view in extending his travels from Italy not only to other classic lands: to Greece and North Africa, but he also visited Constantinople, and traveled in Germany and England as well as in France. His catholicity of taste is shown by his frankly expressed admiration — somewhat unusual among French architects — for the architecture of England during the Medieval and early Renaissance periods. He was, for instance, particularly struck by the beauty of Cambridge.

This brief statement will, it is hoped, have made clear the chief reasons why the Department of Architecture feels itself singularly fortunate in being able to add Professor Duquesne to its permanent staff. After looking over the whole field, in this country and abroad, the University has selected the man who seemed to be best fitted to fill this important position, and it has secured him.

HARVARD ENGINEERING JOURNAL

A QUARTERLY

DEVOTED TO THE INTERESTS OF ENGINEERING AND ARCHITECTURE AT HARVARD UNIVERSITY

THE OFFICIAL ORGAN OF THE ASSOCIATION OF HARVARD ENGINEERS

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"Harvard still has a long lead in that dyed-in-wool allegiance which counts most powerfully for the university's prestige." So comments a writer in the daily press in comparing Harvard with another university. True of Harvard men with diversified interests, it should be doubly true of Harvard Engineers having, as

they do, specific interests. But with the engineer, the allegiance counts most powerfully for that portion of the University known as the Graduate School of Applied Science.

Now that the Association of Harvard Engineers is co-operating with the undergraduates in the affairs of the JOURNAL, each member of the Association is urged to take a lively interest in the growth of this publication, and show his allegiance by continuing his subscription, sending items relating to his engineering work to the editor, and when the spirit moves, preparing an article.

The object of both the Association and the undergraduates is to publish a magazine which shall be to Harvard Engineers what the *Harvard Graduates' Magazine* is to all Harvard men. To do this requires more income; the amount of income possible will depend on the development of a subscription list large enough to attract the advertising of manufacturers of engineering products. Therefore the JOURNAL wants the subscription of every Harvard man interested in engineering and the Graduate School of Applied Science.

The JOURNAL begs to announce that articles by the following have been definitely promised for publication in the tenth volume: —

George H. Clark, of Columbia University. An article on the new Brooklyn Dry Dock.

Francis P. Coffin, '03, of the Research Laboratory of the General Electric Company, Schenectady. "The Mercury Arc Rectifier."

F. W. Dean, '75, Mill Engineer and Architect, Boston. "Mill Engineering."

Arthur B. Green, '07, with the New York Public Service Commission. An article on the New York Subway.

Chester B. Lewis, '07, with C. W. Humphry, Chicago. "Civil and Hydraulic Features of the plant of the Northern Illinois Light and Traction Company at Marseilles, Illinois."

O. A. Mailloux, of Mailloux & Knox, Consulting Electrical Engineers, New York. The final installment of an article on "Train Resistance," continued from Vol. V, No. 1.

L. G. Morphy, Designing Engineer for the Boston & Albany Railroad. A lecture, "Terminal Facilities for Handling Steam Locomotives," delivered before the Harvard Engineering Society of New York at their meeting of January 14.

Frank R. Pleasanton, '07. An article on steel manufacture.

Frederick Pope, '01, of the Standard Turpentine Company, Jacksonville, Fla. An article on the turpentine process.

Ralph R. Rumery, '98. "Engineers and Civic Affairs."

Edward C. Sherman, Designing Engineer, Isthmian Canal Commission. "A Study of a Hydraulic Problem of the Panama Canal."

Charles P. Steinmetz, h., '02, Consulting Engineer of the General Electric Company, Schenectady, and others.

H. F. Tucker, '01, Designing Engineer, Isthmian Canal Commission. An article on a new alloy.

The article on the appointment of Professor Eugene Duquesne, which appears in this issue, may well be considered as authoritative, written as it is by Professor H. L. Warren, to whose efforts, direct and indirect, the coming of Professor Duquesne is largely due.

In response to a number of inquiries, the Editor would state that the article by Mr. Guy F. Shaffer, entitled "An Investigation of the Corrosion of Iron Imbedded in Concrete," which appeared in the November issue, was a brief abstract of his thesis presented for the degree of Bachelor of Science in Architectural Engineering at the Massachusetts Institute of Technology.

In connection with Mr. James G. Patterson's article on "Boston's New Telephone Rates" in the November number, the following changes in nomenclature, in effect December 12, are important: —

"Central District" for the group of seven exchanges hitherto known as Metropolitan.

"Suburban District" for each suburban exchange district, to be further distinguished by adding the exchange which is its center.

The word "Metropolitan" will be used in future to define the area comprised by the Central and Suburban Districts as a whole, and also to designate the grades of service which without payment of toll cover this entire area.

Also, on page 163, line 8, of the article the words "five mile" should be omitted.

ASSOCIATION OF HARVARD ENGINEERS

The annual meeting of the Association of Harvard Engineers will be held on March 11th in the Harvard Union. The business meeting, at six o'clock, will be followed as usual by a dinner at which the Association members will be joined by the undergraduate Harvard Engineering Society. The list of speakers is not yet ready, but it is expected that President Lowell will be present and will speak to the graduates and undergraduates.

A list of magazine articles, written by Association members, that have come to our attention since last issue, is given below.

The Buddle as a Concentrator of Copper Slimes (illustrated): Claude T. Rice, *Eng'g & Mining Journal,* Vol. 90, No. 23; Dec. 3, 1910.

The Clinkering of Coal: Results of Test for Effect of Various Constituents in the Ash (illustrated): Lionel S. Marks, *Eng'g News,* Vol. 64, No. 23, Dec. 8, 1910.

Development of the Goldfield Mines: Claude T. Rice, *Eng'g & Mining Journal,* Vol. 91, No. 2; Jan. 14, 1911.

The Mines of Butte in 1910: B. B. Thayer, *Eng'g & Mining Journal,* Vol. 91, No. 1; Jan. 7, 1911.

Railway Passenger and Freight Terminals in Large Cities: Frederic A. Delano, *Eng'g News,* Vol. 65, No. 1; Jan. 5, 1911.

Revised Flow Sheet of Utah Copper Mill (illustrated): Claude T. Rice, *Eng'g & Mining Journal,* Vol. 90, No. 26; Dec. 24, 1910.

Limitations of Efficiency in Engineering Education; G. F. Swain; (extracts from address at Union College;) *Eng'g Record,* Vol. 62, No. 25; Dec. 17, 1910.

Value of Geological Work in Limestone Regions; Claude T. Rice, *Eng'g & Mining Journal,* Vol. 90, No. 24; Dec. 10, 1910.

Waterways, Their Limitations and Possibilities: F. A. Delano, *Eng'g News,* Vol. 64, No. 26; Dec. 29, 1910.

Names to be added to the list of members since are:

BEDFORD, RUSSELL BOOTH, 1900

With American Blower Co., 141 Broadway, New York, N. Y., and 307 No. Fullerton Ave., Montclair, N. J.

BOHLIN, GUSTAF SAMUEL, A.B. 1910..

With N. Y., N. H. & H. R. R.

23 Trinity St., New Rochelle, N. Y.

PRAY, JAMES STURGIS, A.B. 1895.

Senior partner, Pray, Hubbard & White, Boston, *and* Chairman, Dept. of Landscape Arch., H.U.

50 Garden St., Cambridge, Mass.

WHITTEMORE, PARKER W., A.B. 1895.

Lacoma Car Co. 141 Milk St., Boston, Mass.

WOLFARD, MERL RUSKIN, M.M.E. 1910.

Asst. Mech. Eng'g, H.U.

17 Hammond St., Cambridge, Mass.

CHANGES OF ADDRESSES

BEGIEN, R. N., Asst. to Gen'l M'g'r, B. & O. R. R., Baltimore, Md.

BRINTON, W. C., 611 Whitney Ave., Wilkinsburg Station, Pittsburg, Pa.

DOYEN, G. E., Turner Construction Co., New York City.

HERSCHEL, W. H., 236 Newbury St., Boston, Mass.

WITHINGTON, SIDNEY, Care N. H. R. R., Hartford, Conn.

HARVARD ENGINEERING SOCIETY OF NEW YORK

The second regular meeting and excursion of the Society for the year 1910-11 were held on Saturday, January 14.

An excursion was made in the afternoon to the new Grand Central Terminal and the new York Public Library. About seventy-five members and guests assembled in the waiting room of the New York Central Railroad at 2.30. The party was conducted by four of the railroad engineers connected with the work, going first to a construction office where a plaster model of the new station was on exhibition, and then following along Park Avenue, where the open-cut work could be seen from the street above. A small party in charge of one of the engineers ventured into the open-cut on the operating level.

The party re-assembled at the new Library near-by, and were met there by several men from the office of Carrere & Hastings, the architects, who acted as guides through the building.

Following the excursion, about thirty-five members went to the Harvard Club for dinner.

The regular business meeting was held at the Harvard Club in the evening. After the meeting, Mr. L. G. Morphy, Designing Engineer of the Boston & Albany Railroad, gave a very interesting lecture on "Steam Locomotive Terminals."

Final arrangements are being made for the annual dinner of the Society, which will take place at the Harvard Club on the evening of Friday, February 24. President Emeritus Charles W. Eliot and Mr. Howard C. Elliott, President of the Northern Pacific Railroad, have accepted the invitation of the Society to be present and to address the members. There will be several other speakers.

CHARLES GILMAN, *Secretary.*

HARVARD ENGINEERING SOCIETY

The second meeting of the Society for the year was held on the evening of Friday, December 16, in Pierce 110, and was the most successful in some time, there being about one hundred present. Mr. L. K. Rourke, Boston Commissioner of Public Works, lectured on the "Panama Canal."

Mr. Rourke in an extremely interesting talk, took up the main difficulties confronting the engineers in charge of the work: the control of the Chagres River, and the stamping out of the yellow fever prevailing in the Zone. He then showed how efficiently the work was being done under the Government, in a much cheaper and more effective way than any private concern could hope to do it. He also pointed out that the main uses of the Canal will be to act as a check on the freight rates of the transcontinental roads, and to aid in the defense of our coasts by bringing the Atlantic and Pacific fleets more closely together in point of time. With reference to the latter point, Mr. Rourke favored fortifying the Canal so that it would at least be neutral in war time.

The third regular meeting was held on the evening of Monday, January 23, in Pierce 110. The speaker was Mr. F. B.

Freeman, the Chief Engineer of the Boston & Albany Railroad, who spoke on the "Relation of a College Education to the Railroad Service." After emphasizing the fact that a liberal education should not only give a student learning, but also character, of which the second is by far the most important, he outlined the possibilities of railroad work, its fascinations, and its responsibilities.

The meeting was well attended and the members were enthusiastic over the talk.

The Committee which has been appointed to arrange for the Annual Dinner of the Association of Harvard Engineers and the Harvard Engineering Society on March 11 is as follows:

Walter H. Durfee, 3G, *Chairman.*
E. A. Healey, 1G.
F. W. Hill, '12.
R. Murray, '12.
P. C. Nash, '11.
G. H. Roosevelt, '13.

PHILIP C. NASH, *Secretary.*

HARVARD ELECTRICAL CLUB

The first regular meeting of the year was held on the evening of Monday, December 2, at the home of Professor A. E. Kennelly. Professors Adams, Clifford, and Kennelly spoke briefly, Professor Clifford outlining his ideas as to the possibilities of the Club meetings.

After the business meeting, the Club was entertained by Professor and Mrs. Kennelly.

HUGH L. DAVIS, *Secretary.*

HARVARD MINING CLUB

The second regular meeting of the Club was held in the Trophy Room of the Union on Friday evening, December 9. The speaker of the evening was Mr. Waldemar Lindgren, of the United States Geological Survey, who told of many of his experiences with the Survey in a most interesting way.

After the meeting, refreshments were served.

RAY P. DUNNING, *Secretary.*

HARVARD AERONAUTICAL SOCIETY

The second moving picture exhibit of aeroplanes, dirigibles, and balloons was held in Brattle Hall on the evening of Monday, December 19. One of the most interesting films shown was one of the late Ralph Johnstone performing the "spiral glide." The exhibit was thoroughly satisfactory as showing the advance of the science since the previous exhibition held by the Society in 1909.

Some little work has been done in reconstructing the glider of the Society by the Glider Section, under the direction of R. M. Allen, '11, who was elected Manager by the Board of Directors early in December.

The arrangements for the second annual meet are being perfected; it will be held on the field at Atlantic from August 26 to September 4, provided the approval of these dates by the National Council of Aero Clubs is obtained. Mr. Claude Graham-White has already consented to come, and it is expected that many of the well-known aviators will be present.

EDWIN C. BROWN, *Secretary.*

GRADUATE NOTES

(*On account of the many inquiries as to the whereabouts of the graduates of the department, it is hoped that the Editor will be notified of changes of address or occupation, etc. Such notes will appear promptly in this column.*

Other notes of graduates will be found under the notice of the Association, in this issue.)

Albert Brown, '90; Howard Whitney, '95; Ernest Moses, '99; John Ware, '99; Ernest Kimball, '05; and William S. Hall, are in the Elevated and Subway Construction Department of the Boston Elevated.

Greely S. Curtis, '92, is Treasurer of the Burgess Company & Curtis, Manufacturers of Aeroplanes and Aviation Engineers, Marblehead, Mass.

H. H. Cook, '93, has been appointed Assistant of the newly established American Iron and Steel Institute of New York.

P. P. Sharples, '95, is head of the road building department in Boston of the Barrett Manufacturing Company.

Edwin H. Brown, '96, is an architectural engineer, with offices at 716 Fourth Avenue South, Minneapolis.

Walter A. Hall, '96, is assistant to the manager of the Lynn works of the General Electric Company. For several years he has been at the company's factory in Pittsfield, Mass. Present address: 15 Hardy Road, Swampscott, Mass.

Joseph Edmund Woodman, '96, is Mining Geologist and Professor of Geology, New York University, New York City.

John H. Fedeler, '97, has recently been appointed Superintendent of the new New York Public Library, 11 West 40th Street, New York City.

E. L. Verveer, '98, is contracting engineer for the Alfred E. Norton Company of New York City.

G. C. Kimball, '00, is chief engineer of the American Sheet and Tin Plate Company, which has its general offices in the Frick Building, Pittsburg.

R. P. Perry, '00, is the Cleveland manager of the manufacturing department of the Barrett Manufacturing Company.

F. W. Daggett, '99, is Superintendent of Construction for Fred T. Ley & Co., Inc., 29 Broadway, New York City.

Francis Mason, '99, has recently organized the contracting firm of Mason, Hilton & Co., 17 Battery Place, New York City.

Samuel L. Wonson, '99, is general bridge inspector for the Missouri Pacific Railway, with headquarters at Saint Louis. Address: 5225 Kensington Avenue, Saint Louis, Mo.

Corey C. Brayton, '01, is general superintendent of operation of the rock crushing department of the Natomas Consolidated of California. Address: 203 Hagelstein Building, Sacramento, Cal.

Frederick Pope, '01, is Chief Engineer Southern Mfg. Co. and Vice-President and Ch. Engr. Standard Turpentine Co., Jacksonville, Fla.

A. L. Sweetser, '01, is now with the Colorado Department of the Telluride Power Company, having charge of the Ames and Ilium stations. He recently contributed two papers to the Bulletin of the American Institute of Mining Engineers, entitled "Chlorination of Gold Ores, — Laboratory Tests," and "Lixiviation of Low Grade Copper Ores."

Francis B. Wilby, a student in the Scientific School in 1900-01, and a graduate of the West Point Military Academy in 1905, is now First Lieutenant in the Engineer Corps, and at present is on duty at Manila. His permanent address is Office of the Chief of the Engineer Corps, Washington, D. C.

Niran Bates Pope, '02, is Editor of the *Motor World,* 154 Nassau Street, New York City.

Harrison Weymouth, '02, is connected with F. W. Bird & Son, in charge of their Western New York office, located at Rochester, N. Y.

Henry E. Mead, '03, is connected with Gunn, Richards & Co. as Productive and Industrial Engineer, 43 Exchange Place, New York City.

Arthur Nortman, '03, is Chief Geologist for the Copper Queen Consolidated Mining Co., Bisbee, Ariz.

James A. Wilson, '03, has recently taken a position as manufacturing Engineer with the Ogden Iron & Steel Co., 147 Cedar Street, New York City.

Ralph C. Bean, '04, who has been Instructor of Science in the Wakefield (Massachusetts) High School, has resigned to accept a similar position in the Boston Girls' Latin School.

H. G. Ferguson, '04, a geologist in the Philippine Bureau of Science, recently gave a lecture in Cambridge, before the Geological Conference, on "Geological Problems in the Philippine Islands."

Harry W. Andrews, '05, is with the American Bridge Company, Clay Street, Brooklyn, N. Y.

Walter S. Gifford, '05, is Statistician for the American Telephone and Telegraph Co., 15 Dey Street, New York City.

The marriage is announced of Lulu Agatha Liesemer, daughter of Mr. and Mrs. Louis J. Liesemer, to Edward E. White, S.B., '05, M.E., '06, on January 7 at Ann Harbor, Michigan. At home after March first at Ishpeming, Mich.

Quincy A. Brackett, '06, is an electrical engineer with the Westinghouse Electrical and Manufacturing Company at Pittsburg. Address: 806 Franklin Avenue, East Wilkinsburg, Pa.

O. D. Filley, '06, has returned to Mexico to do prospecting work. Permanent address: 412 Beacon Street, Boston, Mass.

Leslie R. Coffin, '06, is manager of the Whatcom County Railway and Light Co. of Bellingham, Wash., one of the companies controlled by Stone & Webster.

Arthur C. Comey, '07, formerly superintendent of parks at Utica, N. Y., is now landscape architect with the Milwaukee County Park Commission, under John Nolen, A.M., '05, as advisory landscape architect, in city planning work. His present address is the University Club, Milwaukee.

Harry P. Forté, '07, is the mechanical engineer for the Beech-Nut Packing Company. Address: Canajoharie, N. Y.

Harry D. Gaylord, '07, who for the past two years has been teaching at the Throop Polytechnic Institute, Pasadena, Cal., is this year an instructor in mathematics in Harvard College. Address: 98 Hemenway Street, Boston.

Lawrence W. Hayes, '07, is in the mechanical department of R. Hoe & Company, manufacturers of printing presses, 504 Grand Street, New York City. Address: 153 Taylor Street, Brooklyn, N. Y.

F. Rodney Pleasanton, '07, is with the Pennsylvania Steel Co. Address: P. O. Box 102, Steelton, Pa.

Lyman C. Josephs, '08, at present in the employ of the Westinghouse Company, has been given work in the new Pennsylvania Tunnel under the North River. His duties include the instruction of the Pennsylvania's motormen in the operation of the new electric engines.

Harold LeR. Olmstead, '08, was married to Miss Grace Legate, daughter of Burton J. Legate, '77, on June 28, 1910, at Leominster, Mass. At present he is studying architecture abroad, and intends to remain in Europe for a couple of years. Address until end of April, care of American Express Co., Rome. Later in the spring he intends to settle in Paris for further study.

Henry A. Richardson, '08, has recently taken a position with the New York Central & Hudson River R. R. Co. in the Engineering Dept., New York City.

G. G. Browne, '10, is in Cambridge for the present assisting Professor H. J. Hughes in his work on a book on hydraulics. During the past autumn he was doing railroad construction work in eastern Kentucky.

Joseph J. Mahoney, '10, formerly with the Siegel Company, in Boston, is now in the statistical department of the Western Electric Company, New York City. Address: 116 West 13th Street, New York City.

Charles A. Merrill, '10, is with the Baltimore and Ohio Railroad Company. Present address: 216 Pearl Street, Grafton, W. Va.

Harmar Morse, '10, is with the Nichols and Drown Company, Heating and Ventilating, Lynn and Boston. Address: 23 Crowdrey Avenue, Lynn, Mass.

Edward B. Robins, Jr., '10, is now with the Portland Railway, Light and Power Co. of Portland, Ore. Address: 163 Seventeenth Street, Portland, Ore.

Edward S. Wolston, '10, is an engineer on electrification work for the New York, New Haven, and Hartford Railroad, at Mount Vernon, N. Y. Address: 55 Fletcher Avenue, Mount Vernon.

MISCELLANEOUS NOTES

Among *recent publications* by members of the staff were: —

"The Clinkering of Coal: Results of Tests for the Effect of Various Constituents in the Ash," by L. S. Marks. *Engineering News,* December 8, 1910.

Reviews, by L. S. Marks. "American Producer Gas Practice," by Latta; "Cours des Machines Marines," by Jauch and Masmejean. *Engineering News,* June 15, 1910. "Heat Engines," by Allen and Bursley. *Engineering News,* October 13, 1910. "Applied Thermodynamics for Engineers," by W. D. Ennis; "Applied Thermodynamics" by H. W. Spangler. *Engineering News,* November 17, 1910.

"A Study of Practicable Copper Slags," by E. D. Peters. *The Mineral Industry,* November, 1910.

"Deutsche und Romanische Flussterminologie," by W. M. Davis. *Geographischer,* pp. 121-123. 1910.

"Geographical Essays," by W. M. Davis. (Edited by D. W. Johnson.) Boston, Ginn & Co., 1910. 777 pp.

"Notes on the Description of Land Forms," by W. M. Davis. *Bulletin of the American Geographical Society,* 42: 671-675. 1910.

"Experiments in Geographical Description," by W. M. Davis. (Presidential Address, Association of American Geographers, December 30, 1909.) *Bulletin of the American Geographical Society,* 42: 401-435, 1910. Also in *Science,* 31: 921-946, 1910; and *Scotland Geographical Magazine,* 26: 561-586, 1910.

"Vector-Diagrams of Oscillating-Current Circuits," by A. E. Kennelly. *Proceedings of the American Academy of Arts and Sciences,* January, 1911.

PERSONAL NOTES

Mr. John Guernsey Callan, who was for several years with the General Electric Company, and is with the firm of Arthur D. Little of Boston, delivered a series of nine lectures on the team Turbine in Pierce 110, on Mondays, Wednesdays, and Fridays from January 4 to 23. These lectures were planned for a review of the subject for the general student whose knowledge of mathematics and thermodynamics would not permit him to go into details of design. They were illustrated with stereopticon views.

At a recent meeting of the National Academy of Sciences, held at Saint Louis, Mo., November 8 to 10, Professor W. M. Davis gave the results of his Western summer studies in a paper, entitled "The Front Range of the Rocky Mountains in Colorado." On November 11 he lectured on the Colorado Cañon, in the State Museum at Springfield, Ill., and then spent a week, November 12 to 19, at the University of Illinois, where he delivered seven lectures on "Geography as a University Subject." At the annual meeting of the Geological Society of America, held December 27 to 29, Professor Davis read a paper entitled "Geographical Descriptions in the Folios of the Geologic Atlas of the United States." He was elected President of the Society for 1911.

Professor H. J. Hughes addressed the Cambridge Club on Monday, December 12, on "Economical Width of Paved Way."

At a joint meeting of mathematicians and engineers, held in Minneapolis, Minn., on December 30, under the auspices of the Chicago Section of the American Mathematical Society and Sections A and D of the American Association for the Advancement of Science, a preliminary report of the Committee on the Teaching of Mathematics to Students of Engineering was presented by the chairman, Professor E. V. Huntington.

Professor A. E. Kennelly lectured before the Society of Sigma Chi at the University of Pennsylvania on Friday, January 13, on "The Differences between Telegraphy and Telephony, Wireless and by Wires."

Professor L. S. Marks was called to New York City during the recess to investigate the explosion in the new Grand Central Terminal Station.

At the annual meeting of the American Society of Landscape Architects, held in New York City on January 10, Professor J. S. Pray was elected to fill the annual vacancy in the Executive Committee, to serve until 1914.

Professor A. Lawrence Rotch lectured on Saturday evening, December 10, before the Dartmouth Scientific Society, in Hanover, N. H., on "The Air and its Navigation."

Professor G. F. Swain spoke before the Mechanics Arts students on Monday, January 6.

Professor H. L. Warren delivered the following set of illustrated lectures at the Brooklyn Institute of Arts and Sciences on successive Thursdays from November 10 to December 8: —

1. "The Development of the English Home to the Close of the Reign of Elizabeth." 2. "The English Home from James I to the Georges." 3. "Georgian House Architecture in the American Colonies." 4. "The Planning and Designing of the House of To-Day. (a) Houses of Moderate Cost in City and Country." 5. "The Planning and Designing of the House of To-Day. (b) Houses of More Expensive Type."

ADDITIONS AND CHANGES IN COURSES OF STUDY

Engineering 16p, "Electric Transmission and Distribution of Power," and Engineering 17b, "Telegraphy and Telephony" will, in future, be associated with fifteen hours of laboratory work each.

A new course in the Architectural Department is proposed for next year, to be called "Architectural Acoustics," and to be given by Professor W. C. Sabine. Other new courses are under consideration.

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